DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
ANNA UNIVERSITY, CHENNAI – 25

VISION:

The vision of the department is to produce analytically proficient and technologically competent Electrical and Electronics Engineers who can serve and take forward the academic, industry and research organizations to newer heights and be effective for building the nation.

MISSION:

- To impart high quality technical education with the state of the art laboratory practice.
- To provide conducive academic ambience to enable best teaching and learning processes.
- To generate resources through research and consultancy projects for pursuing research and developmental activities in emerging areas.
- To associate with academic and industrial organizations for research activities to develop and provide vital and viable solutions for social needs indigenously.
- To develop leadership skills in students with high degree of ethics, morals and values and instill confidence to lead the organization.

ANNA UNIVERSITY, CHENNAI
UNIVERSITY DEPARTMENTS
REGULATIONS - 2023
CHOICE BASED CREDIT SYSTEM
M.E.POWER ELECTRONICS AND DRIVES

CURRICULUM AND SYLLABUS I TO IV SEMESTERS

1. PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

I.	To have successful career in electrical power industries, research and academic institutions with lifelong learning and professional ethics.
II.	To analyze, design and develop power electronic converters / drive systems for sustainable energy technologies.
III.	To become an entrepreneur and develop indigenous technology to meet the requirements of the societal needs.

2. PROGRAMME OUTCOMES (POs)

On successful completion of the programme, the graduate would have	
PO1	An ability to independently carry out research / investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report / document.
PO3	Students should be able to demonstrate a degree of mastery in power electronics and drives.
PO4	Apply knowledge of basic science and engineering science to analyze, design and testing of power electronic systems and drives with high power density and efficiency.
PO5	Design analog and digital controllers for power electronic systems and drives.
PO6	Design and develop power converters for extracting maximum energy and utilization of renewable energy sources.

3. MAPPING OF PEOs with POs

PEO	**PO**					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
I	3	-	3	2	2	-
II	3	1	3	1	3	3
III	2	-	3	1	1	-

Mapped with 1, 2, 3 & -, scale: 1-low; 2-medium; 3-high; '-' no correlation.

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PROGRAM ARTICULATION MATRIX

		Course Name	PO1	PO2	PO3	PO4	PO5	PO6
YEAR 1	Semester 1	Applied Mathematics for Electrical Engineers	3	-	1	3	-	-
		Research Methodology and IPR	-	3	-	-	-	-
		Modelling of Electrical Machines	3	-	2	3	-	-
		Analysis of Power Converters	3	-	2	3	-	3
		Analog and digital controllers for PE systems	2	1	3	2	3	-
		Professional Elective I	-	-	-	-	-	-
		Power Converters Laboratory	3	2	3	3	-	-
	Semester 2	Analysis of Electrical Drives	3	-	3	3	3	-
		Special Electrical Machines	3	-	2	3	2	-
		Power Electronics for Renewable Energy Systems	**2.8**	**2**	**2.6**	**1.5**	**2.2**	**2.8**
		Modelling and Design of SMPS	3	-	3	3	-	3
		Professional Elective II	-	-	-	-	-	-
		Professional Elective III	-	-	-	-	-	-
		Power Electronics and Drives Laboratory	**2**	**1.75**	**2**	**1.75**	**3**	**2**
		Analog and Digital Controllers for Power Electronic Converter Laboratory	**1.5**	**1.67**	**1.67**	**1.67**	**2**	**1**
YEAR 2	Semester 3	Professional Elective IV	-	-	-	-	-	-
		Professional Elective V	-	-	-	-	-	-
		Professional Elective VI	-	-	-	-	-	-
		Project Work I	-	-	-	-	-	-
	Semester 4	Project Work II	-	-	-	-	-	-

ANNA UNIVERSITY, CHENNAI
UNIVERSITY DEPARTMENTS
M.E. POWER ELECTRONICS AND DRIVES
REGULATIONS – 2023
CHOICE BASED CREDIT SYSTEM
CURRICULUM AND SYLLABUS I TO IV SEMESTERS

SEMESTER I

S. No.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	MA3156	Applied Mathematics for Electrical Engineers	FC	4	0	0	4	4
2.	RM3151	Research Methodology and IPR	RMC	2	1	0	3	3
	PE3152	Modelling of Electrical Machines	PCC	3	0	0	3	3
4.	PE3151	Analysis of Power Converters	PCC	3	0	0	3	3
5.	PE3101	Analog and Digital Controllers for PE Systems	PCC	3	0	0	3	3
6.		Professional Elective I	PEC	3	0	0	3	3
PRACTICALS								
7.	PE3111	Power Converters Laboratory	PCC	0	0	4	4	2
			TOTAL	**18**	**1**	**4**	**23**	**21**

SEMESTER II

S. No.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	PE3251	Analysis of Electrical Drives	PCC	3	0	0	3	3
2.	PE3252	Special Electrical Machines	PCC	3	0	0	3	3
3.	PE3201	Power Electronics for Renewable Energy Systems	PCC	2	0	2	4	3
4.	PE3202	Modelling and Design of SMPS	PCC	3	0	0	3	3
5.		Professional Elective II	PEC	3	0	0	3	3
6.		Professional Elective III	PEC	3	0	0	3	3
PRACTICALS								
7.	PE3211	Power Electronics and Drives Laboratory	PCC	0	0	4	4	2
8.	PE3212	Analog and Digital Controllers for SMPS Laboratory	PCC	0	0	4	4	2
			TOTAL	**17**	**0**	**10**	**27**	**22**

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SEMESTER III

S. No.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.		Professional Elective IV	PEC	3	0	0	3	3
2.		Professional Elective V	PEC	3	0	0	3	3
3.		Professional Elective VI	PEC	3	0	0	3	3
PRACTICALS								
4.	PE3311	Project Work I	EEC	0	0	12	12	6
			TOTAL	**9**	**0**	**12**	**21**	**15**

SEMESTER IV

S. No.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICALS								
1.	PE3411	Project Work II	EEC	0	0	24	24	12
			TOTAL	0	0	24	24	12

TOTAL NO. OF CREDITS: 70

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REGULATIONS – 2023
CHOICE BASED CREDIT SYSTEM
M.E. POWER ELECTRONICS AND DRIVES (PART TIME)
CURRICULAM AND SYLLABUS I TO VI SEMESTERS

SEMESTER I

S.NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	MA3156	Applied Mathematics for Electrical Engineers	FC	4	0	0	4	4
2.	RM3151	Research Methodology and IPR	RMC	2	1	0	3	3
3.	PE3151	Analysis of Power Converters	PCC	3	0	0	3	3
PRACTICALS								
4.	PE3111	Power Converters Laboratory	PCC	0	0	4	4	2
			TOTAL	**9**	**1**	**4**	**14**	**12**

SEMESTER II

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	PE3251	Analysis of Electrical Drives	PCC	3	0	0	3	3
2.	PE3202	Modelling and Design of SMPS	PCC	3	0	0	3	3
3.		Professional Elective I	PEC	3	0	0	3	3
PRACTICALS								
4.	PE3211	Power Electronics and Drives Laboratory	PCC	0	0	4	4	2
			TOTAL	**9**	**0**	**4**	**13**	**11**

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SEMESTER III

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	PE3152	Modelling of Electrical Machines	PCC	3	0	0	3	3
2.	PE3101	Analog and Digital Controllers for PE Systems	PCC	3	0	0	3	3
3.		Professional Elective II	PEC	3	0	0	3	3
			TOTAL	**9**	**0**	**0**	**9**	**9**

SEMESTER IV

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	PE3252	Special Electrical Machines	PCC	3	0	0	3	3
2.	PE3201	Power Electronics for Renewable Energy Systems	PCC	2	0	2	4	3
3.		Professional Elective III	PEC	3	0	0	3	3
PRACTICALS								
4.	PE3212	Analog and Digital Controllers for SMPS Laboratory	PCC	0	0	4	4	2
			TOTAL	**8**	**0**	**6**	**14**	**11**

SEMESTER V

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.		Professional Elective IV	PEC	3	0	0	3	3
2.		Professional Elective V	PEC	3	0	0	3	3
3.		Professional Elective VI	PEC	3	0	0	3	3
PRACTICALS								
4.	PE3311	Project Work I	EEC	0	0	12	12	6
			TOTAL	**9**	**0**	**12**	**21**	**15**

SEMESTER VI

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICALS								
1.	PE3411	Project Work II	EEC	0	0	24	24	12
			TOTAL	**0**	**0**	**24**	**24**	**12**

TOTAL NO. OF CREDITS: 70

FOUNDATION COURSE (FC)

S. No.	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			L	T	P		
1.	MA3156	Applied Mathematics for Electrical Engineers	4	0	0	4	1

RESEARCH METHODOLOGY AND IPR COURSE (RMC)

S. NO	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			L	T	P		
1.	RM3151	Research Methodology and IPR	2	1	0	3	1
					TOTAL CREDITS	**3**	

PROFESSIONAL CORE COURSES (PCC)

S. No.	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			L	T	P		
1.	PE3101	Analog and Digital Controllers for PE	3	0	0	3	1
2.	PE3151	Analysis of Power Converters	3	0	0	3	1
3.	PE3152	Modelling of Electrical Machines	3	0	0	3	1
4.	PE3111	Power Converters Laboratory	0	0	4	2	1
5.	PE3251	Analysis of Electrical Drives	3	0	0	3	2
6.	PE3252	Special Electrical Machines	3	0	0	3	2
7.	PE3201	Power Electronics for Renewable Energy Systems	2	0	2	3	2
8.	PE3202	Modelling and Design of SMPS	3	0	0	3	2

9.	PE3211	Power Electronics and Drives Laboratory	0	0	4	2	2
10.	PE3212	Analog and Digital Controllers for SMPS Laboratory	0	0	4	2	2
					TOTAL CREDITS	27	

PROFESSIONAL ELECTIVE COURSES (PEC)

S. No.	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS
			L	T	P	
1.	PE3001	Power Semiconductor Devices	3	0	0	3
2.	PE3054	Rectifiers and Resonant Converters	3	0	0	3
3.	PE3055	Vector Control of AC Machines	3	0	0	3
4.	PE3053	Power Quality	3	0	0	3
5.	PE3051	Control of Power Electronic Circuits	3	0	0	3
6.	PE3002	Advanced Power Converters	3	0	0	3
7.	PE3003	Product Development and Design Standards for Power Electronics Systems	3	0	0	3
8.	PE3052	Multilevel Converters	3	0	0	3
9.	PE3004	Nonlinear Dynamics for Power Electronic Circuits	3	0	0	3

PROFESSIONAL ELECTIVES COURSES (PEC)

(OFFERED BY OTHER P.G. PROGRAMMES)

S. NO.	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS
			L	T	P	
1	PS3052	Distributed Generation and Micro Grid	3	0	0	3
2	PS3152	HVDC and FACTS	3	0	0	3
3	PS3252	Smart Grid	3	0	0	3
4	PS3054	Wind Energy Conversion Systems	3	0	0	3
5	PS3053	Optimization Techniques to Power System Engineering	3	0	0	3
6	PW3052	Electric Vehicles and Power Management	3	0	0	3
7	PW3151	Electric Vehicle Charging Infrastructure	3	0	0	3

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8	PW3251	Energy Storage Systems	3	0	0	3
9	PW3051	Design and Modelling of Solar PV Systems	3	0	0	3
10	PW3054	Grid Integration of Renewable Energy Sources	3	0	0	3
11	CO3151	Control System Design	4	0	0	4
12	CO3152	Intelligent Controllers	3	0	0	3
13	CO3252	Non Linear Control	3	1	0	4
14	CO3055	Model Predictive Control	3	0	0	3
15	CO3058	System Theory	3	0	0	3
16	CO3053	Industrial Internet of Things	3	0	0	3
17	ET3054	Embedded Controllers for EV Applications	3	0	0	3
18	ET3252	Embedded Control for Electric Drives	2	0	2	3
19	ET3061	Machine Learning and Deep Learning	3	0	0	3
20	ET3067	Unmanned Aerial Vehicle	3	0	0	3
21	ET3060	IoT for Smart Systems	3	0	0	3
22	ET3152	VLSI Design and Reconfigurable Architecture	3	0	0	3
23	ET3063	Python Programming for Machine Learning	3	0	0	3
24	ET3062	MEMS and NEMS Technology	3	0	0	3
25	ET3065	Robotics and Automation	3	0	0	3
26	ET3051	Big Data Analytics	3	0	0	3
27	HV3152	Electromagnetic Field Computation and Modelling	3	0	0	3
28	HV3052	Electromagnetic Interference and Compatibility	3	0	0	3

EMPLOYABILITY ENHANCEMENT COURSES (EEC)

S. No.	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			L	T	P		
1.	PE3311	Project Work I	0	0	12	6	3
2.	PE3411	Project Work II	0	0	24	12	4
					TOTAL CREDITS	18	

SUMMARY

S. No	SUBJECT AREA	CREDITS PER SEMESTER				CREDITS TOTAL
		I	II	III	IV	
1.	FC	4	-	-	-	4
2.	PCC	11	16	-	-	27
3.	PEC	3	6	9	-	18
4.	RMC	3	-	-	-	3
5.	EEC	-	-	6	12	18
6.	**TOTAL CREDITS**	**21**	**22**	**15**	**12**	**70**

MA3156 APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS **L T P C**
4 0 0 4

UNIT I MATRIX THEORY 12

The Cholesky decomposition - Generalized Eigen vectors, Canonical basis - QR factorization - Least squares method - Singular value decomposition

UNIT II CALCULUS OF VARIATIONS 12

Concept of variation and its properties – Euler's equation – Functionals dependant on first and higher order derivatives – Functionals dependant on functions of several independent variables – Variational problems with moving boundaries - Direct methods: Ritz and Kantorovich methods

UNIT III ONE DIMENSIONAL RANDOM VARIABLES 12

Random variables - Probability function – moments – moment generating functions and their properties – Binomial, Poisson, Geometric, Uniform, Exponential, Gamma and Normal distributions – Function of a Random Variable

UNIT IV LINEAR PROGRAMMING 12

Formulation – Graphical solution – Simplex method – Two phase method - Transportation and Assignment Models

UNIT V FOURIER SERIES 12

Fourier Trigonometric series: Periodic function as power signals – Convergence of series – Even and odd function: cosine and sine series – Non-periodic function: Extension to other intervals - Power signals: Exponential Fourier series – Parseval's theorem and power spectrum

TOTAL: 60 PERIODS

OUTCOMES:

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

- Apply the concepts of Matrix theory in Electrical Engineering problems.
- Use calculus of variation techniques to solve various engineering problems.
- Solve electrical engineering problems involving one-dimensional random variables.
- Formulate and solve linear programming problems in electrical engineering.
- To solve engineering problems using Fourier series techniques.

REFERENCES:

1. Andrews L.C. and Phillips R.L., Mathematical Techniques for Engineers and Scientists, Prentice Hall of India Pvt. Ltd., New Delhi, 2005.
2. Elsgolts, L., Differential Equations and the Calculus of Variations, MIR Publishers, Moscow, 2003.
3. Grewal, B.S., Higher Engineering Mathematics, Khanna Publishers, 44th Edition, New Delhi, 2017.
4. Gupta, A.S., Calculus of Variations with Applications, Prentice Hall of India Pvt. Ltd., New Delhi, 2004.
5. Johnson R. A. and Gupta C. B., "Miller & Freund's Probability and Statistics for Engineers", Pearson Education, 8th Edition, New Delhi, 2015.
6. Oliver C. Ibe, "Fundamentals of Applied Probability and Random Processes, Academic Press, (An imprint of Elsevier), Boston, 2014.

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7. O'Neil, P.V., Advanced Engineering Mathematics, Thomson Asia Pvt. Ltd., 8th Edition, Singapore, 2017.
8. Richard Bronson, "Matrix Operation", Schaum's outline series, McGraw Hill, Second Edition, New York, 2011.
9. Taha, H.A., "Operations Research, An introduction", Pearson education, 10th Edition, New Delhi, 2017.

MAPPING OF COs WITH POs

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

RM3151 RESEARCH METHODOLOGY AND IPR LT P C
2 1 0 3

UNIT I RESEARCH PROBLEM FORMULATION 9

Objectives of research, types of research, research process, approaches to research; conducting literature review- information sources, information retrieval, tools for identifying literature, Indexing and abstracting services, Citation indexes, summarizing the review, critical review, identifying research gap, conceptualizing and hypothesizing the research gap

UNIT II RESEARCH DESIGN AND DATA COLLECTION 9

Statistical design of experiments- types and principles; data types & classification; data collection - methods and tools

UNIT III DATA ANALYSIS, INTERPRETATION AND REPORTING 9

Sampling, sampling error, measures of central tendency and variation,; test of hypothesis- concepts; data presentation- types of tables and illustrations; guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript; guidelines for writing thesis, research proposal; References – Styles and methods, Citation and listing system of documents; plagiarism, ethical considerations in research

UNIT IV INTELLECTUAL PROPERTY RIGHTS 9

Concept of IPR, types of IPR – Patent, Designs, Trademarks and Trade secrets, Geographical indications, Copy rights, applicability of these IPR; , IPR & biodiversity; IPR development process, role of WIPO and WTO in IPR establishments, common rules of IPR practices, types and features of IPR agreement, functions of UNESCO in IPR maintenance.

UNIT V PATENTS 9

Patents – objectives and benefits of patent, concept, features of patent, inventive steps, specifications, types of patent application; patenting process - patent filling, examination of patent, grant of patent, revocation; equitable assignments; Licenses, licensing of patents; patent agents, registration of patent agents.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of the course, the student can

CO1: Describe different types of research; identify, review and define the research problem

CO2: Select suitable design of experiment s; describe types of data and the tools for collection of data

CO3: Explain the process of data analysis; interpret and present the result in suitable form

CO4: Explain about Intellectual property rights, types and procedures

CO5: Execute patent filing and licensing

REFERENCES:

1. Cooper Donald R, Schindler Pamela S and Sharma JK, "Business Research Methods", Tata McGraw Hill Education, 11e (2012).
2. Soumitro Banerjee, "Research methodology for natural sciences", IISc Press, Kolkata, 2022,
3. Catherine J. Holland, "Intellectual property: Patents, Trademarks, Copyrights, Trade Secrets", Entrepreneur Press, 2007.
4. David Hunt, Long Nguyen, Matthew Rodgers, "Patent searching: tools & techniques", Wiley, 2007.
5. The Institute of Company Secretaries of India, Statutory body under an Act of parliament, "Professional Programme Intellectual Property Rights, Law and practice", September 2013.

PE3152 MODELLING OF ELECTRICAL MACHINES **LT P C**
3 0 0 3

UNIT I PRINCIPLES OF ELECTRO MAGNETIC ENERGY CONVERSION 9

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

UNIT II DC MACHINES 9

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

UNIT III REFERENCE FRAME THEORY 9

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

UNIT IV INDUCTION MACHINES 9

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

UNIT V SYNCHRONOUS MACHINES 9

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

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1: Ability to optimally design magnetics required in power supplies and drive systems.
CO2: Ability to acquire and apply knowledge of mathematics of machine dynamics in Electrical engineering.
CO3: Ability to model, simulate and analyze the dynamic performance of electrical machines using computational software.
CO4: Ability to formulate, design, simulate power supplies and loads for complete electrical machine performance
CO5: Ability to verify the results of the dynamic operation of electrical machine systems

TEXT BOOKS:

1. Paul C.Krause, Oleg Wasyzczuk, Scott S, Sudhoff, “Analysis of Electric Machinery and Drive Systems”, John Wiley, Second Edition, 2010.
2. R Ramanujam,”Modelling and Analysis of Electrical Machines”, I.K International Publishing Pvt. Ltd., New Delhi, 2018

REFERENCES:

1. P S Bimbhra, “Generalized Theory of Electrical Machines”, Khanna Publishers, 2008.
2. A.E, Fitzgerald, Charles Kingsley, Jr, and Stephan D, Umanx, “Electric Machinery”, Tata McGraw Hill, 5th Edition,199

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	3	-	1
CO2	3	3	2	3	-	1
CO3	3	3	2	3	-	1
CO4	3	3	2	3	-	1
CO5	3	3	2	3	-	1
Average	**3**	**3**	**2**	**3**	**-**	**1**

PE3151 ANALYSIS OF POWER CONVERTERS

L T P C
3 0 0 3

UNIT I SINGLE PHASE AC-DC CONVERTER 9

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

UNIT II THREE PHASE AC-DC CONVERTER 9

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

UNIT III SINGLE PHASE INVERTERS 9

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

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

UNIT V MODERN INVERTERS 9

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

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1: Ability to acquire and apply knowledge of mathematics in power converter analysis.
CO2: Ability to model, analyze and understand power electronic systems and equipment.
CO3: Ability to formulate, design and simulate phase-controlled rectifiers for generic load and for machine loads.
CO4: Ability to formulate, design, simulate switched mode inverters for generic load and for machine loads.
CO5: Ability for device selection and calculation of performance parameters of power converters under various operating modes.

TEXT BOOKS:

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

REFERENCES:

1 P.C.Sen, “Modern Power Electronics”, Wheeler Publishing Co,First Edition, New Delhi, 1998.

2 P.S.Bimbhra, “Power Electronics”, Khanna Publishers, Eleventh Edition, 2003.

3 Bin Wu, Mehdi Narimani, "High-power Converters and AC Drives", Wiley, 2nd Edition, 2017.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	2	3	2
CO2	2	2	2	2	3	2
CO3	2	1	2	1	3	1
CO4	2	2	2	2	3	1
CO5	2	2	2	2	3	2
Average	**2**	**1.8**	**2**	**1.8**	**3**	**1.6**

PE3101 ANALOG AND DIGITAL CONTROLLERS FOR PE SYSTEMS L T P C
3 0 0 3

UNIT I FIRING SCHEMES OF VARIOUS CONVERTERS 9

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

UNIT II INTEGRATION OF VOLTAGE AND CURRENT SENSORS FOR FEEDBACK 9

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

UNIT III 8051 BASED CONTROL SCHEMES 9

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

UNIT IV PIC MICRO-CONTROLLER BASED CONTROL SCHEMES 9

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

UNIT V ARDUINO MICRO-CONTROLLER BASED CONTROL SCHEMES 9

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

TOTAL = 45 PERIODS

COURSE OUTCOMES:

After completing the above course, students will be able to:

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

TEXT BOOKS:

1. Kenneth Ayala, The 8051 micro-controller, fourth Edition, Thomson India Edition, 2014.
2. John B Peatman Designing with PIC micro-controllers, Pearson Education, 2005.
3. Neerparaj Rai, Arduino projects for Engineers, BPB publications, 2016.

REFERENCES:

1. G K Dubey, Doradla, Sinha, Introduction to power electronics,
2. Ned Mohan, Undeland and, Power Electronics: Devices, converters, and applications.
3. M H Rashid, Power Electronics.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	2	3	2
CO2	2	2	2	2	3	2
CO3	2	1	2	1	3	1
CO4	2	2	2	2	3	1
CO5	2	2	2	2	3	2
Average	**2**	**1.8**	**2**	**1.8**	**3**	**1.6**

PE3111 **POWER CONVERTERS LABORATORY** **L T P C**
0 0 4 2

LIST OF EXPERIMENTS:

To simulate

1. Single phase / three phase half controlled converter fed RL load.
2. Single phase / three phase fully controlled converter fed RLE load.
3. Single phase VSI fed RL/RC load.
4. Three phase VSI fed RLE load.
5. Three phase ZSI fed RLE load.
6. Design of UPS.
7. Design of SMPS.
8. Diode Clamped multilevel inverter.
9. Flying Capacitor multilevel inverter.
10. Cascaded type multilevel inverter

TOTAL : 60 PERIODS

COURSE OUTCOMES:

Upon the successful completion of the course, students will have:

CO1: Ability to acquire and apply knowledge of mathematics in power converter / machine dynamics.
CO2: Ability to model and analyze phase controlled rectifier circuits using computational software.
CO3: Ability to model and analyze switches mode inverter circuits using computational software.
CO4: Ability to formulate, design, simulate power supplies for generic load and for machine loads.
CO5: Ability to model and analyze multi-level inverter topologies using computational software.

REFERENCES:

1. Ned Mohan, T.M.Undeland and W.P Robbin, "Power Electronics: converters, Application and design" John Wiley and sons. Wiley India edition, 2006.
2. Rashid M.H., "Power Electronics Circuits, Devices and Applications ", Prentice Hal India, New Delhi, 1995.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	2	3	2
CO2	2	2	2	2	3	2
CO3	2	1	2	1	3	1
CO4	2	2	2	2	3	1
CO5	2	2	2	2	3	2
Average	**2**	**1.8**	**2**	**1.8**	**3**	**1.6**

SEMESTER II

PE3251 ANALYSIS OF ELECTRICAL DRIVES **LT P C 3 0 0 3**

UNIT I DC MOTORS FUNDAMENTALS AND MECHANICAL SYSTEMS 9

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

UNIT II CONVERTER AND CHOPPER CONTROL 9

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

UNIT III CLOSED LOOP CONTROL 9

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

UNIT IV VSI AND CSI FED STATOR CONTROLLED INDUCTION MOTOR CONTROL 9

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

UNIT V ROTOR CONTROLLED INDUCTION MOTOR DRIVES 9

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

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1: Ability to acquire and apply knowledge of mathematics and converter/machine dynamics in Electrical engineering.
CO2: Ability to formulate, design, simulate power supplies for generic load and for machine loads.
CO3: Ability to analyze, comprehend, design and simulate direct current motor based adjustable speed drives.
CO4: Ability to analyze, comprehend, design and simulate induction motor based adjustable speed drives.
CO5: Ability to design a closed loop motor drive system with controllers for the current and speed control operations.

TEXT BOOKS:

1. Gopal K Dubey, “Power Semiconductor controlled Drives”, Prentice Hall Inc., NewYersy, 1989.
2. R.Krishnan, “Electric Motor Drives – Modeling, Analysis and Control”,Prentice-Hall of India Pvt. Ltd., New Delhi,2010.
3. Bimal K Bose, “Modern Power Electronics and AC Drives”, Pearson Education Asia2002.

REFERENCES:

1. Gopal K.Dubey, “Fundamentals of Electrical Drives”, Narosal Publishing House, New Delhi, Second Edition, 2009.
2. .Vedam Subramanyam, “Electric Drives – Concepts and Applications”, Tata McGraw-Hill publishing company Ltd., New Delhi, 2002.
3. P.C Sen “Thyristor DC Drives”, John wiely and sons, New York, 1981.
4. W.Leonhard, “Control of Electrical Drives”, Narosa Publishing House, 1992.
5. Murphy J.M.D and Turnbull, “Thyristor Control of AC Motors”, Pergamon Press, Oxford, 1988.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	2	3	2
CO2	2	2	2	2	3	2
CO3	2	1	2	1	3	1
CO4	2	2	2	2	3	1
CO5	2	2	2	2	3	2
Average	**2**	**1.8**	**2**	**1.8**	**3**	**1.6**

PE3252 **SPECIAL ELECTRICAL MACHINES** **LT P C**
3 0 0 3

UNIT I PERMANENT MAGNET BRUSHLESS DC MOTORS 9

Fundamentals of Permanent Magnets - Types- Principle of operation- Magnetic circuit analysis- Mechanical and Electronic Commutation - Hall Sensors- EMF and Torque equations- Characteristics – Inductance Calculation - Radial and Axial Flux Machines.

UNIT II PERMANENT MAGNET SYNCHRONOUS MOTORS 9

Rotor Configurations - EMF and Torque equations – Synchronous reactance - Phasor diagram - Power controllers – Circle Diagram - Torque speed characteristics – Torque / Ampere and kVA / kW for Sine wave and Square wave motors - Synchronous reluctance motor.

UNIT III SWITCHED RELUCTANCE MOTORS 9

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

UNIT IV STEPPER MOTORS 9

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

UNIT V OTHER SPECIAL MACHINES 9

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

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1: Ability to model and analyze power electronic systems and equipment using computational software.
CO2: Ability to optimally design magnetics required in special machines based drive Systems using FEM based software tools.
CO3: Ability to analyse the dynamic performance of special electrical machines
CO4: Ability to understand the operation and characteristics of other special electrical machines.
CO5: Ability to design and conduct experiments towards research.

TEXT BOOKS:

1. T.J.E. Miller, ‘Brushless magnet and Reluctance motor drives’, Claredon press, London, 1989.
2. R.Krishnan, ‘Switched Reluctance motor drives’, CRC press, 2001.
3. T.Kenjo, ‘Stepping motors and their microprocessor controls’, Oxford University press, New Delhi, 2000.

REFERENCES:

1. T.Kenjo and S.Nagamori, ‘Permanent magnet and Brushless DC motors’, Clarendon press, London, 1988.
2. R.Krishnan, ‘Electric motor drives’, Prentice hall of India, 2002.
3. D.P.Kothari and I.J.Nagrath, ‘ Electric machines’, Tata McGraw hill publishing company, New Delhi, Third Edition,2004.
4. Irving L.Kosow, “Electric Machinery and Transformers” Pearson Education, Second Edition, 2007.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	2	3	2
CO2	2	2	2	2	3	2
CO3	2	1	2	1	3	1
CO4	2	2	2	2	3	1
CO5	2	2	2	2	3	2
Average	**2**	**1.8**	**2**	**1.8**	**3**	**1.6**

PE3201	POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS	LT P C 2 0 2 3

UNIT I INTRODUCTION TO RENEWABLE ENERGY SYSTEMS **6**

Introduction- Impacts of renewable energy generation on the environment – GHG effect, Qualitative study of renewable energy resources: Ocean, Biomass, Geothermal, Hydrogen energy systems, Solar Photovoltaic (PV) system, Wind Energy system and Fuel cells.

UNIT II POWER ELECTRONIC CONVERTERS FOR RENEWABLE ENERGY **6**

Solar: Line commutated converters (inversion mode) - Boost and buck-boost converters.
Wind: Three phase AC voltage controllers- AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid Interactive Inverters- multi-source converter.

UNIT III PHOTO VOLTAIC ENERGY CONVERSION SYSTEMS **6**

Introduction, Photo Voltaic (PV) effect, Solar Cell, Types, Equivalent circuit of PV cell, PV cell characteristics (I/V and P/V) for variation of insolation, temperature and shading effect, Stand-alone PV system, Grid connected PV system, Design of PV system-load calculation, array sizing, selection of converter/inverter, battery sizing.

UNIT IV WIND ENERGY CONVERSION SYSTEMS **6**

Introduction, Power contained in wind, Efficiency limit in wind, types of wind turbines, Wind control strategies, Power curve and Operating area, Types of wind generators system based on Electrical machines-Induction Generator and Permanent Magnet Synchronous Generator (PMSG), Grid Connected-Single and Double output system, Self-excited operation of Induction Generator and Variable Speed PMSG.

UNIT V HYBRID RENEWABLE ENERGY SYSTEMS **6**

Energy Storage systems, Need for Hybrid Systems- Range and type of Hybrid systems- Case studies of Diesel-PV, Wind-Diesel, Wind-PV, Maximum Power Point Tracking (MPPT) algorithms.

LAB COMPONENT **30**

1. Performance characteristics of solar PV panel
2. VI characteristics of fuel cell.
3. Performance characteristics and MPPT tracking of SEIG based wind turbine.
4. Performance characteristics and MPPT tracking of DFIG based wind turbine.
5. Performance characteristics and MPPT tracking of PMSG based wind turbine.

L= 30 P=30 TOTAL 60 PERIODS

COURSE OUTCOMES:

Upon completion of the course, students will be able to:
CO1: Ability to understand different renewable energy systems
CO2:!!Ability to design and simulate power electronics converters used for interfacing renewable energy systems
CO3: Ability to design PV Solar energy systems.
CO4: Ability to design Wind energy conversion systems.
CO5: Ability to design hybrid energy system and extract maximum power using MPPT algorithms

TEXT BOOKS:

1. Robert W. Erickson & Dragon Maksimovic, ”Fundamentals of Power Electronics”, Second Edition, 2001 Springer science and Business media.

REFERENCES:

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

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	1	1	1	2
CO2	3	2	3	-	2	3
CO3	3	2	3	3	2	3
CO4	3	2	3	1	3	3
CO5	3	2	3	1	3	3
Average	**2.8**	**2**	**2.6**	**1.5**	**2.2**	**2.8**

PE3202 MODELLING AND DESIGN OF SMPS

L	T	P	C
3	0	0	3

UNIT I DESIGN OF CONVERTER CIRCUITS **9**

Revision of Buck, Boost, Buck-boost and Cuk converters - Discontinuous conduction mode – Derivation of current ripple and voltage ripple formulae based on volt-sec balance and charge balance concepts - Design of critical inductance – Selection of capacitors

UNIT II ANALYSIS OF ISOLATED DC-DC CONVERTERS **9**

Introduction - classification- forward- flyback- pushpull- halfbridge- fullbridge topologies- design of SMPS

UNIT III MODELING OF SMPS CONVERTERS **9**

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

UNIT IV CONTROLLER DESIGN **9**

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 DESIGN OF MAGNETICS **9**

Basic magnetic theory revision – Inductor design – Design of mutual inductance – Design of transformer for isolated topologies – Ferrite core table and selection of area product – wire table – selection of wire gauge.

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1 Ability to understand the operation of non-isolated and isolated converters.
CO2 Ability to design Non-Isolated DC-DC converters
CO3 Ability to design Isolated DC-DC converter.
CO4 Ability to derive transfer function of different converters.
CO5 Ability to design controllers for DC DC converters.
CO6 Ability to design magnetics for SMPS applications

TEXT BOOKS:

1. Robert W. Erickson & Dragon Maksimovic, " Fundamentals of Power Electronics", Second
2. Edition, 2001 Springer science and Business media

REFERENCES:

1. John G. Kassakian, Martin F. Schlecht, George C. Verghese, "Principles of Power Electronics",
2. Pearson, India, New Delhi, 2010.
Philip T Krein, " Elements of Power Electronics", Oxford University Press, 2017.
3. Ned Mohan, "Power Electronics: A first course", John Wiley,2012.
4. Issa Batarseh, Ahmad Harb, "Power Electronics- Circuit Analysis and Design, Second edition.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	1	3	2	1
CO2	2	2	1	2	3	2
CO3	2	2	1	2	3	2
CO4	3	2	1	3	2	1
CO5	2	2	1	2	3	2
CO6	2	2	2	3	1	1
Average	**2.6**	**2.4**	**1.4**	**3**	**2.8**	**1.8**

PE3211 **POWER ELECTRONICS AND DRIVES LABORATORY** **L T P C**
0 0 4 2

LIST OF EXPERIMENTS:

1. Speed control of Converter fed DC motor.
2. Speed control of Chopper fed DC motor.
3. V/f control of three-phase induction motor.
4. Micro controller based speed control of Stepper motor.
5. Speed control of BLDC motor.
6. DSP based speed control of SRM motor.
7. Voltage Regulation of three-phase Synchronous Generator.
8. AC voltage Controller based speed control of induction motor.
9. Computation of magnetic flux density and Inductance for magnetic circuits with air gap
10. Static and transient analysis using FE software for
    i) BLDC motor ii) SRM motor iii) PMSM

TOTAL : 60 PERIODS

COURSE OUTCOMES:

CO1: Ability to formulate, design, simulate and conduct experiments for speed control of converter fed drives.
CO2: Ability to optimally design magnetics required in power supplies and drive systems.
CO3: Ability to understand the various power electronic controllers used in drive systems.
CO4: Ability to conduct static and transient analysis of electrical machines using FE software

REFERENCES:

1. Ned Mohan, T.M. Undeland and W.P Robbin, “Power Electronics: converters, Application and design” John Wiley and sons. Wiley India edition, 2006.
2. Rashid M.H., “Power Electronics Circuits, Devices and Applications ", Prentice Hal India, New Delhi, 1995.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	2	3	2
CO2	2	2	2	2	3	2
CO3	2	1	2	1	3	2
CO4	2	2	2	2	3	2
Average	**2**	**1.75**	**2**	**1.75**	**3**	**2**

PE3212 ANALOG AND DIGITAL CONTROLLERS FOR SMPS LABORATORY **L T P C**
0 0 4 2

LIST OF EXPERIMENTS:

1. 555 timer based chopper firing scheme for open-loop controlled boost converter.
2. 555 timer based feed-forward controller for a buck-boost/ C'uk converter.
3. OPAMP based Butterworth Filter design and verification
4. OPAMP based Time-Ratio Control firing pulse generation.
5. Single phase AC – DC converter firing scheme using analog circuit components.
6. Waveform generation by using Look-Up Table.
7. Duty-cycle control using a Potentiometer connected to ADC peripheral in a stand-alone mode.
8. Design of MOSFET driver circuit using IR2110 / TLP 250 / IR 4427.
9. Design and testing of signal conditioning circuit to interface voltage/current sensor with micro-controller.
10. ON/ OFF controller design and verification using analog circuits/ micro-controller.
11. Design of closed-loop P, I and PI controllers using OPAMP.
12. Design of closed-loop P, I and PI controllers using micro-controller.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

After completing the above course, students will be able to:

CO1. Identify suitable analog controller for the Switching Mode Power Converter
CO2. Understand the need for usage of gate driver ICs / circuits.
CO3. Understand the need for signal conditioning circuits while interfacing the feedback sensors.
CO4. Analyze critically and select various controllers with strategies for design.
CO5. Implement analog controllers for real-time SMPS applications.
CO6. Implement digital controllers for real-time SMPS applications.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	1	2	2	1
CO2	1	1	1	2	2	-
CO3	1	2	2	2	2	-
CO4	2	2	2	2	2	1
CO5	2	2	2	1	2	1
CO6	2	2	2	1	2	1
Average	**1.5**	**1.67**	**1.67**	**1.67**	**2**	**1**

PROFESSIONAL ELECTIVES

PE3001 POWER SEMICONDUCTOR DEVICES **LT P C**
3 0 0 3

UNIT I INTRODUCTION 9
Power switching devices overview – Attributes of an ideal switch, application requirements, circuit symbols; Power handling capability – (SOA); Power diodes – Types, forward and reverse characteristics, switching characteristics – rating. Features and Brief History of Silicon Carbide- Promise and Demonstration of SiC Power Devices- Physical Properties of Silicon Carbide devices –Unipolar and Bipolar Diodes- GaN Technology Overview.

UNIT II CURRENT CONTROLLED DEVICES 9
BJT's – Construction, static characteristics, switching characteristics; Negative temperature coefficient and second breakdown; - Thyristors – Construction, working, static and transient characteristics, types, series and parallel operation; comparison of BJT and Thyristor – steady state and dynamic models of BJT &Thyristor- Basics of GTO, SiC based Bipolar devices- Applications- Building a GaN Transistor – GaN Transistor Electrical Characteristics.

UNIT III VOLTAGE CONTROLLED DEVICES 9
Power MOSFETs and IGBTs – Principle of voltage controlled devices, construction, types, static and switching characteristics, steady state and dynamic models of MOSFET and IGBTs – and IGCT. New semiconductor materials for devices – Intelligent power modules - study of modules like APTGT100TL170G, MSCSM70TAM05TPAG. Integrated gate commutated thyristor (IGCT) - SiC based unipolar devices-applications.

UNIT IV DEVICE SELECTION , DRIVING and PROTECTING CIRCUITS 9
Device selection strategy – On-state and switching losses – EMI due to switching. Necessity of isolation, pulse transformer, optocoupler – Gate drive integrated circuit: Study of Driver IC – IRS2110/2113. SCR, MOSFET, IGBTs and base driving for power BJT. – Over voltage, over current and gate protections; Design of snubbers.

UNIT V THERMAL PROTECTION 9
Heat transfer – conduction, convection and radiation; Cooling – liquid cooling, vapour – phase cooling; Guidance for hear sink selection – Thermal resistance and impedance –Electrical analogy of thermal components, heat sink types and design – Mounting types- switching loss calculation for power device.

TOTAL : 45 PERIODS

OUTCOMES:
After completing the above course, students will be able to
- CO1: Identify suitable device for the application and to learn the characteristics of voltage and current controlled power devices.
- CO2: Know the advantages of Silicon Carbide devices and Galium Nitride devices.
- CO3: Understand the principles and characteristics of Silicon devices, Silicon Carbide devices and Galium Nitride devices.
- CO4: Design proper driving circuits and protection circuits.
- CO5: Construct a proper thermal protective devices for power semiconductor devices.

Attested

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Centre for Academic Courses
Anna University, Chennai-600 025

REFERENCES:

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

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	-	-
CO2	3	3	3	3	-	-
CO3	3	3	3	3	-	-
CO4	3	3	3	3	-	-
CO5	3	3	3	3	-	-
Average	**3**	**3**	**3**	**3**	**-**	**-**

PE3054 RECTIFIERS AND RESONANT CONVERTERS **L T P C**
3 0 0 3

UNIT I PULSE WIDTH MODULATED RECTIFIERS 9

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

UNIT II VIENNA RECTIFIER 9

VIENNA Rectifiers- Principle of Operation and Analysis - Block Diagram of the Controller - Converter Design.

UNIT III RESONANT CONVERTERS 9

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

UNIT IV SOFT SWITCHING IN THREE PHASE CONVERTERS 9

Soft-switching Technique for Three-phase Converters, Applications of Soft-switching to Three-phase Converters, Switching Transient Process and Switching Loss, Diode Turn-off and Reverse Recovery, Stray Inductance on Switching Process, Classification of Soft-switching Three-phase Converters, DC-side Resonance Converters, Resonant DC-link Converters, Active-clamped Resonant DC-link (ACRDCL) Converter.

UNIT V CONTROL OF PWM RECTIFIRS 9

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

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1: Able to understand the working of pulse width modulated rectifier.
CO2: Capacity to design power factor correction rectifiers.
CO3: Capable in designing the resonant converters.
CO4: Analyse the concept of soft switching in three phase converters.
CO5: To design an appropriate controller for PWM rectifiers.

REFERENCES:

1. John G. Kassakian, Martin F. Schlecht, George C. Verghese, “Principles of Power Electronics”, Pearson, India, New Delhi, 2010.
2. Philip T Krein, “Elements of Power Electronics”, Oxford University Press, 1998.
3. Ned Mohan, “Power Electronics: A first course”, John Wiley, 2011.
4. Issa Batarseh, Ahmad Harb, “Power Electronics- Circuit Analysis and Design, Second edition, 2018.
5. Dehong Xu, Rui Li, Ning He, Jinyi Deng, Yuying Wu, Soft-Switching Technology for Three-phase Power Electronics Converters, IEEE Press, 2022.
6. Fang Lin Luo, Hong Ye, Power Electronics Advanced Conversion Technologies, Second edition, CRC Press, 2018.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	-	-
CO2	3	3	3	3	-	-
CO3	3	3	3	3	-	-
CO4	3	3	3	3	-	-
CO5	3	3	3	3	3	-
Average	**3**	**3**	**3**	**3**	**3**	**-**

PE3055 VECTOR CONTROL OF AC MACHINES

L	T	P	C
3	0	0	3

UNIT I VECTOR CONTROL OF PM SYNCHRONOUS MACHINE 9

Introduction-Smooth Air gap machine and salient pole machines- flux linkage space phasors- voltage equation- expression for electromagnetic torque. PMSM with surface mounted magnets- control scheme for of rotor oriented controlled PMSM with interior magnets

UNIT II VECTOR CONTROL OF SALIENT POLE MACHINE WITH ELECTRICALLY EXCITED ROTOR 9

Magnetizing flux oriented control –variable frequency operation of salient pole synchronous machine-rotor oriented control of reluctance machines-considerations of the effects of main flux saturation

UNIT III STATOR FLUX ORIENTED CONTROL OF INDUCTION MACHINE 9

Squirrel cage machine -Electromagnetic torque-voltage equations, doubly fed induction machines-control-static converter cascade

UNIT IV ROTOR FLUX ORIENTED CONTROL OF INDUCTION MACHINE 9

Control by a VSI – voltage equation-decoupling circuits- electromagnetic torque-voltage equations- current controlled PWM inverter- control by CSI – current controlled operation - control of slip ring induction machines

UNIT V MAGNETIC FLUX ORIENTED CONTROL OF INDUCTION MACHINE 9

The magnetizing flux oriented control of induction machine: Control by a VSI – voltage equation-decoupling circuits- electromagnetic torque-voltage equations- current controlled PWM inverter.

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1: Ability to carry out space phasor model for electrical machines.
CO2: Ability to synthesis the vector controller for surface mount permanent magnet synchronous machines.
CO3: Able to synthesis the vector controller for buried type permanent magnet synchronous machines.
CO4: Able to compute and analyze the controllers of salient pole machines.
CO5: Able to understand and select the various control schemes suitable for induction motor.
CO6: Ability to comprehend the flux oriented control concepts of induction motor drive.

TEXT BOOKS:

1. Peter Vas, “Vector control of AC machines/Peter Vas”, Oxford [England]: Clarendon Press; New York: Oxford University Press, 1990.
2. BimalK.Bose, “Modern Power Electronics and AC Drives”, Prentice Hall PTR, 2002.
3. D. W. Novotny, T. A. Lipo, Vector Control and Dynamics of AC Drives, Clarendon

Press, 1996.
4. Nguyen Phung Quang, Jörg-Andreas Dittrich, , Vector Control of Three-Phase AC Machines: System Development in the Practice Springer, 2015

REFERENCES:

1. Peter Vas, "Sensorless Vector and Torque Control", Oxford University press, 1998.
2. PaulC.Krause, Oleg Wasyzczuk, Scott S, Sudhoff, "Analysis of Electric Machinery and Drive Systems", John Wiley, Second Edition, 2010.
3. Andrzej M. Trzynadlowski, The Field Orientation Principle in Control of Induction Motors Springer, 1994
4. Andrzej M. Trzynadlowski, Control of Induction Motors, Academic Press, 2000.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1	2	2	1
CO2	2	2	1	2	1	1
CO3	2	2	1	2	2	1
CO4	2	2	1	2	2	1
CO5	2	2	1	2	2	1
CO6	2	2	1	2	2	1
Average	**2.17**	**2**	**1**	**2**	**1.83**	**1**

PE3053 POWER QUALITY

L	T	P	C
3	0	0	3

UNIT I INTRODUCTION 9

Introduction – Characterization of Electric Power Quality: Transients, short duration and long duration voltage variations, Voltage imbalance, waveform distortion, Voltage fluctuations, Power frequency variation, Power acceptability curves – power quality problems: poor load power factor, Non-linear and unbalanced loads, DC offset in loads, Notching in load voltage, Disturbance in supply voltage – Power quality standards.

UNIT II ANALYSIS OF SINGLE PHASE AND THREE PHASE SYSTEM 9

Single phase linear and non-linear loads –single phase sinusoidal, non-sinusoidal source – supplying linear and non-linear load – three phase Balance system – three phase unbalanced system – three phase unbalanced and distorted source supplying non-linear loads – concept of PF – three phase three wire – three phase four wire system.

UNIT III CONVENTIONAL LOAD COMPENSATION METHODS 9

Principle of load compensation and voltage regulation – classical load balancing problem : open loop balancing – closed loop balancing, current balancing – harmonic reduction and voltage sag reduction– analysis of unbalance – instantaneous of real and reactive powers – Extraction of fundamental sequence component from measured.

UNIT IV LOAD COMPENSATION USING DSTATCOM 9

Compensating single – phase loads – Ideal three phase shunt compensator structure – generating reference currents using instantaneous PQ theory – Instantaneous symmetrical components theory – Generating reference currents when the source is unbalanced –Realization and control of DSTATCOM – DSTATCOM in Voltage control mode.

UNIT V SERIES COMPENSATION OF POWER DISTRIBUTION SYSTEM 9

Rectifier supported DVR – DC Capacitor supported DVR – DVR Structure – voltage Restoration – Series Active Filter – Unified power quality conditioner.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1 Ability to understand consequences of Power quality issues.
CO2 Ability to conduct harmonic analysis of single phase and three phase systems supplying non-linear loads.
CO3 Ability to design passive filter for load compensation.
CO4 Ability to design active filters for load compensation.
CO5 Ability to understand the mitigation techniques using custom power devices such as distribution static compensator (DSTATCOM), dynamic voltage restorer (DVR) & UPQC.

TEXTBOOKS:

1. Arindam Ghosh "Power Quality Enhancement Using Custom Power Devices", Kluwer Academic Publishers, 2002.

2. G.T.Heydt, "Electric Power Quality", Stars in a Circle Publications, 1994 (Second edition).

REFERENCES:

1. R.C.Duggan Electric Power Systems Quality, Tata MC Graw Hill Publishers, Third Edition, 2012.
2. Arrillga Power System Harmonics, John Wiely and Sons, 2003 Second Edition.
3. Derek A.Paice Power Electronic Converter Harmonics, Wiley – IEE Press 1999, 18th Edition.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	1	1	2	-
CO2	3	-	2	1	1	-
CO3	3	1	3	3	-	-
CO4	3	-	3	3	-	-
CO5	3	1	1	2	3	-
Average	**2.8**	**1**	**2**	**2**	**2**	**-**

PE3051 CONTROL OF POWER ELECTRONIC CIRCUITS L T P C
3 0 0 3

UNIT I CONTROLLER DESIGN FOR BASIC DC-DC CONVERTERS- PART I 9

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

UNIT II CONTROLLER DESIGN FOR BASIC DC-DC CONVERTERS- PART II 9

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

UNIT III CONTROLLER DESIGN FOR BASIC AC-DC CONVERTER CIRCUITS 9

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

UNIT IV SLIDING MODE CONTROL 9

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

UNIT V FLATNESS BASED CONTROL 9

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

TOTAL : 45 PERIODS

COURSE OUTCOMES:

After completing the above course, students will be able to

CO1: Design controller for front end power factor corrector circuits.
CO2: Design controllers for UPS application.
CO3: Design controllers for AC-DC converters.
CO4: Design sliding mode control for power converters.
CO5: Design flatness based control for power converters.

TEXT BOOKS:

1. Hebertt Sira-Ramírez and Ramón Silva-Ortigoza,"Control Design Techniques in Power Electronics Devices " Springer-Verlag London Limited 2006
2. Ned Mohan, "Power Electronics: A First Course", John wiley, 2011
3. Marian K. Kazimierczuk and Agasthya Ayachit,"Laboratory Manual for Pulse-Width Modulated DC–DC Power Converters", Wiley 2016

REFERENCES:

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

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	-	3	-
CO2	3	3	3	-	3	-
CO3	3	3	3	-	3	-
CO4	3	3	3	-	3	-
CO5	3	3	3	-	3	-
Average	**3**	**3**	**3**	**-**	**3**	**-**

PE3002 ADVANCED POWER CONVERTERS **L T P C**
3 0 0 3

UNIT I VOLTAGE-LIFT CONVERTERS 9
Introduction- Self-lift and reverse self-lift circuits- Cuk converter, Luo converter and SEPIC converters- continuous and discontinuous conduction mode.

UNIT II POSITIVE OUTPUT &NEGATIVE OUTPUT SUPER-LIFT LUO-CONVERTERS 9
Main series, -Elementary Circuit, Re-Lift Circuit, Triple-Lift Circuit, Higher-Order Lift Circuit-. Continuous conduction and discontinuous conduction mode.

UNIT III ULTRA LIFT CONVERTERS AND MULTIPLE-QUADRANT OPERATING LUO-CONVERTERS 9
Ultra-Lift Luo- Converter- Operation - Continuous conduction and discontinuous conduction Mode and of Ultra-Lift Luo-Converter-Instantaneous Values- Multiple quadrant operating Luo Converters-Circuit explanations-modes of operation

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 match control- Principle of Dual-Transformer based DAB converter-Three-Level bidirectional DC–DC converter

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

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1: Ability to understand the working of voltage lift circuits.
CO2: Ability to design super lift converters.
CO3: Ability to design ultra-lift converters.
CO4: Ability to understand the working and design of bi-directional DC-DC converters.
CO5: Ability to understand the concepts related with impedance source converter.

Attested

TEXT BOOKS:

1. Advanced DC/DC Converters, Second Edition, Fang Lin Luo, Hong Ye, CRC press, 2018

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2. Impedance source power electronic converters, Yushan Liu , Haitham Abu-Rub , BaomingGe , Dr. Frede Blaabjerg , Omar Ellabban , Poh Chiang Loh, Wiley IEEE press, 2016.
3. High-Frequency Isolated Bidirectional Dual Active Bridge DC–DC Converters with Wide Voltage Gain, Deshang Sha,GuoXu, Springer 2019.

REFERENCES:

1. Essential DC/DC Converters, 1st Edition, Fang Lin Luo, Hong Ye, CRC, 2005
2. Power Electronics Advanced Conversion Technologies, Second Edition, Fang Lin Luo, Hong Ye, 2018 CRC press.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	-	3	-
CO2	3	3	3	-	3	-
CO3	3	3	3	-	3	-
CO4	3	3	3	-	3	-
CO5	3	3	3	-	3	-
Average	**3**	**3**	**3**	**-**	**3**	**-**

PE3003 PRODUCT DEVELOPMENT AND DESIGN STANDARDS FOR POWER ELECTRONICS SYSTEMS **LT P C 3 0 0 3**

UNIT I INTRODUCTION TO PRODUCT DESIGN 9

Need for developing products – the importance of engineering design – types of design –the design process – relevance of product lifecycle issues in design –designing to codes and standards- societal considerations in engineering design –generic product development process – various phases of product development-planning for products –establishing markets- market segments- relevance of market research.

UNIT II PRODUCT ARCHITECTURE 9

Product development management - establishing the architecture - creation - clustering - geometric layout development - Fundamental and incidental interactions - related system level design issues - secondary systems -architecture of the chunks - creating detailed interface specifications-Portfolio Architecture.

UNIT III INDUSTRIAL DESIGN 9

Integrate process design - Managing costs - Robust design - Integrating CAE, CAD, CAM tools – Simulating product performance and manufacturing processes electronically - Need for industrial design-impact – design process - investigation of customer needs - conceptualization - refinement - management of the industrial design process - technology driven products - user - driven products - assessing the quality of industrial design.

UNIT IV DESIGN FOR MANUFACTURING AND PRODUCT DEVELOPMENT Attested **9**

Definition - Estimation of Manufacturing cost-reducing the component costs and assembly costs – Minimize system complexity - Prototype basics - Principles of prototyping - Planning for prototypes -

Economic Analysis - Understanding and representing tasks-baseline project planning - accelerating the project-project execution.

UNIT V TESTS IN INTERACTIVE MODEL 9

Unit test process, Component test process, Integration test process, System integration test process, Acceptance test process, Test automation, Defect fixing and verification, waterfall methodology, Agile methodology.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

CO1: Ability to understand the basic of design of product development.
CO2: Ability to understand the product architecture and layout development
CO3: Ability to design for industrial applications.
CO4: Ability to design for manufacturing and product development
CO5: Ability to test in interactive model of a process.

REFERENCES:

1. Anita Goyal, Karl T Ulrich, Steven D Eppinger, "Product Design and Development ", 4th Edition, 2009, Tata McGraw-Hill Education, ISBN-10-007-14679-9.
2. Product Design and Development, Karl T.Ulrich and Steven D.Eppinger, McGraw –Hill International Edition, 1999.
3. American Metals Society," Non- Destructive Examination and Quality Control", Metal Hand book, Vol 17 9th Metal park, OH, 2012.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	1	1	2	-
CO2	3	-	2	1	1	-
CO3	3	1	3	3	-	-
CO4	3	-	3	3	-	-
CO5	3	1	1	2	3	-
Average	**2.8**	**1**	**2**	**2**	**2**	**-**

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PE3052 MULTILEVEL CONVERTERS **L T P C**
3 0 0 3

UNIT I DIODE CLAMPED MULTILEVEL CONVERTER 9
Introduction – Converter structure and working principle. Pulse Width Modulation (PWM), Sinusoidal Pulse Width Modulation- Bipolar Pulse Width Modulation, Unipolar Pulse Width Modulation, Space vector Pulse Width Modulation – Voltage balance Control.

UNIT II FLYING CAPACITOR MULTILEVEL CONVERTER 9
Introduction – Flying Capacitor Multilevel converter (FCMC) topology – Modulation scheme for the FCMC, Sine PWM, SVPWM – Dynamic voltage balance of FCMC.

UNIT III CASCADED H-BRIDGE MULTILEVEL INVERTERS 9
Introduction - H-Bridge Inverter, Multilevel Inverter Topologies, CHB Inverter with Equal DC Voltage, H-Bridges with Unequal DC Voltages – PWM, Carrier-Based PWM Schemes, Phase-Shifted Multicarrier Modulation, Level-Shifted Multicarrier Modulation, Comparison Between Phase- and Level-Shifted PWM Schemes- Staircase Modulation.

UNIT IV MULTILEVEL CONVERTER WITH REDUCED SWITCH COUNT 9
Multilevel inverter with reduced switch count-structures, working principles and pulse generation methods.

UNIT V MODULAR MULTILEVEL CONVERTERS 9
Fundamentals of Modular Multilevel Converters-Converter Configuration, PWM Schemes -Phase-Shifted and Level shifted-Sampled average-SVPWM techniques-Control of capacitor voltage

TOTAL: = 45 PERIODS

COURSE OUTCOMES:
At the end of the course, students should be able to:
- CO1: Examine the different topologies of multilevel inverters (MLIs) with and without DC link capacitor.
- CO2: Examine the performance of MLIs with Bipolar Pulse Width Modulation (PWM) Unipolar PWM Carrier-Based PWM Schemes Phase Level Shifted Multicarrier Modulation.
- CO3: Demonstrate the working principles of Cascaded H-Bridge MLI, diode clamped MLI, flying capacitor MLI and MLI with reduced switch count.
- CO4: Analyze the voltage balancing performance in Diode clamped MLI.
- CO5: Demonstrate the working principles of modular multilevel converter.

TEXT BOOKS:

1. Sergio Alberto Gonzalez, Santiago Andres Verne, Maria Ines Valla, ”Multilevel Converters for Industrial Applications”, CRC Press, 22-Jul-2013, 2017, First Edition.
2. Fang Lin Luo, Hong Ye,Advanced DC/AC Inverters: Applications in Renewable Energy, CRC Press, 22-Jan-2013, 2017, First Edition.
3. Ersan Kabalcı, Multilevel Inverters Introduction and Emergent Topologies, Academic Press Inc, 2021, First Edition.
4. Iftekhar Maswood, Dehghani Tafti, Advanced Multilevel Converters and Applications in Grid Integration, Wiley, 2018, First Edition.

5. Fujin Deng, Chengkai Liu, Zhe Chen, Modular Multilevel Converters, Control, Fault Detection, and Protection, IEEE Press and Wiley, 2023

REFERENCES:

1. Thomas A. Lipo, Pulse Width Modulation for Power Converters: Principles and Practice, D.Grahame Holmes, John Wiley & Sons, Oct-2003, First Edition.
2. Hani Vahedi, Mohamed Trabelsi, Single-DC-Source Multilevel Inverters, Springer, 2019, First Edition.
3. Bin Wu, Mehdi Narimani, High Power Converters and AC drives by IEEE press 2017, Second Edition.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	-	-
CO2	3	3	3	3	-	-
CO3	3	3	3	3	-	-
CO4	3	3	3	3	-	-
CO5	3	3	3	3	-	-
Average	3	3	3	3	-	-

PE3004 NONLINEAR DYNAMICS FOR POWER ELECTRONIC CIRCUITS **L T P C**
3 0 0 3

UNIT I BASICS OF NONLINEAR DYNAMICS 9

Basics of Nonlinear Dynamics: System, state and state space model, Vector field- Modeling of Linear, nonlinear and Linearized systems, Attractors , chaos, Poincare map, Dynamics of Discrete time system, Lyapunov Exponent, Bifurcations, Bifurcations of smooth map, Bifurcations in piece wise smooth maps, border crossing and border collision bifurcation.

UNIT II TECHNIQUES FOR INVESTIGATION OF NONLINEAR PHENOMENA 9

Techniques for experimental investigation, Techniques for numerical investigation, Computation of averages under chaos, Computations of spectral peaks, Computation of the bifurcation and analyzing stability.

UNIT III NONLINEAR PHENOMENA IN DC-DC CONVERTERS 9

Border collision in the Current Mode controlled Boost Converter, Bifurcation and chaos in the Voltage controlled Buck Converter with latch, Bifurcation and chaos in the Voltage controlled Buck Converter without latch, Bifurcation and chaos in Cuk Converter. Nonlinear phenomenon in the inverter under tolerance band control.

UNIT IV NONLINEAR PHENOMENA IN DRIVES 9

Nonlinear Phenomenon in Current controlled and voltage controlled DC Drives, Nonlinear Phenomenon in PMSM, Induction and SRM Drives.

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UNIT V CONTROL OF CHAOS **9**

Hysteresis control, Sliding mode and switching surface control, OGY Method, Pyragas method, Time Delay control. Application of the techniques to the Power electronics circuit and drives.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Ability to understand, model and simulate chaotic behavior in power electronic systems.

CO2: Ability to investigate the various techniques of nonlinear phenomena.

CO3: Ability to analyze the nonlinear phenomena in DC-DC converter.

CO4: Ability to analyze the nonlinear phenomena in Drives.

CO5: Ability to mitigate chaotic behavior noticed in power system.

TEXT BOOKS:

1. George C. Vargheese, S Banerjee, Nonlinear Phenomenon Power Electronics, Wiley – IEEE Press, July 2001.
2. Steven H Strogatz, Nonlinear Dynamics and Chaos, Westview Press, Second Edition, July 2014.

REFERENCES:

1. C.K.TSE Complex Behaviour of Switching Power Converters, CRC Press, 2003.
2. Alfredo Medio, Marji Lines, “Non Linear Dynamics: A primer”, Cambridge University. Press, 2003.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	2	1	3
CO2	1	2	-	3	3	-
CO3	3	-	1	3	1	-
CO4	3	-	1	1	3	-
CO5	3	-	1	1	2	-
Average	**2.6**	**1.5**	**1.25**	**2**	**2**	**3**

Attested

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PS3052 DISTRIBUTED GENERATION AND MICRO GRID

L	T	P	C
3	0	0	3

UNIT I INTRODUCTION TO DISTRIBUTED GENERATION 9

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

UNIT II DISTRIBUTED ENERGY RESOURCES 9

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

UNIT III DG PLANNING AND PROTECTION 9

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

UNIT IV AC MICROGRID 9

Hierarchical Control: Primary, Secondary and Tertiary Control– Primary Control: Droop Control, Virtual Synchronous Generator Control for VSC – Secondary Control – Simulation Studies

UNIT V DC MICROGRID 9

Hierarchical Control: Primary, Secondary and Tertiary Control – Primary Control: Droop Control, Virtual Inertia Control – Secondary Control: Centralized and Decentralized Control – Simulation Studies

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Students able to

CO1: Understand the concepts of Distributed Generation and Microgrids.

CO2: Gain Knowledge about the various DG resources.

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

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

CO5: Acquire knowledge on the impacts of Microgrid.

REFERENCES:

1. Nick Jenkins, JanakaEkanayake ,GoranStrbac , "Distributed Generation", Institution of Engineering and Technology, London, UK,2010.
2. S. Chowdhury, S.P. Chowdhury and P. Crossley, "Microgrids and Active Distribution Networks", The Institution of Engineering and Technology, London, United Kingdom, 2009.

3. Math H. Bollen ,Fainan Hassan, “Integration of Distributed Generation in the Power System”, John Wiley &Sons, New Jersey, 2011.
4. Magdi S. Mahmoud, Fouad M. AL-Sunni, “Control and Optimization of Distributed Generation Systems”, Springer International Publishing, Switzerland, 2015.
5. Nadarajah Mithulananthan, Duong Quoc Hung, Kwang Y. Lee, “Intelligent Network Integration of Distributed Renewable Generation”, Springer International Publishing, Switzerland, 2017.
6. Ali K., M.N. Marwali, Min Dai, “Integration of Green and Renewable Energy in Electric Power Systems”, Wiley and sons, New Jersey, 2010.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	-	1	-	-
CO2	1	1	1	2	1	-
CO3	1	2	-	1	1	1
CO4	1	1	2	1	2	-
CO5	1	-	1	1	-	1
Average	**1**	**1.33**	**1.33**	**1.2**	**1.33**	**1**

PS3152 HVDC AND FACTS L T P C
3 0 0 3

UNIT I INTRODUCTION 9
Review of basics of power transmission networks-control of power flow in AC transmission line-Analysis of uncompensated AC Transmission line- Passive reactive power compensation: Effect of series and shunt compensation at the mid-point of the line on power transfer- Need for FACTS controllers- types of FACTS controllers-Review of basics of LCC and VSC HVDC system.

UNIT II THYRISTOR BASED FACTS 9
Configuration of SVC- voltage regulation by SVC- Modelling of SVC for power flow analysis-Stability studies- Applications: transient stability enhancement and power oscillation damping of SMIB system with SVC connected at the mid-point of the line-Concepts of Controlled Series Compensation – Operation of TCSC- Analysis of TCSC – Modelling of TCSC for power flow and stability studies.

UNIT III ANALYSIS OF LCC HVDC CONVERTERS AND HVDC SYSTEM CONTROL 9
Pulse number, choice of converter configuration – Simplified analysis of Graetz circuit Converter bridge characteristics – characteristics of a twelve pulse converter- detailed analysis of converters. General principles of DC link control – Converter control characteristics – System control hierarchy - Firing angle control – Current and extinction angle control – Generation of harmonics and filtering - power control – Higher level controllers.

UNIT IV VOLTAGE SOURCE CONVERTER BASED FACTS CONTROLLERS 9
Static synchronous compensator (STATCOM) - Static synchronous series compensator (SSSC) Operation of STATCOM and SSSC-Power flow control with STATCOM and SSSC- Modelling of

STATCOM and SSSC for power flow and transient stability studies –operation of Unified and Interline power flow controllers (UPFC) - Modelling of UPFC for power flow and transient stability studies

UNIT V VOLTAGE SOURCE CONVERTER BASED MTDC SYSTEMS 9

Applications VSC based HVDC: Four quadrant Operation, dq control, PLL dynamics, per unit system for DC Quantities, Modelling for steady state analysis . - Modelling of DC links for dynamics, Solution of DC load flow-Solution of AC- DC power flow: Sequential and Simultaneous methods.

TOTAL: 45 PERIODS

COURSE OUTCOMES

Students will be able to:

CO1: Understand the basics of power transmission networks and need for HVDC and FACTS controllers.

CO2: Analyze the operation, control and application of thyristor based FACTS controllers.

CO3: Analyze the operation, control and application of LCC based HVDC link .

CO4: Analyze the operation, control and application of VSC based HVDC link .

CO5: Model HVDC and FACTS for Power Flow studies.

REFERENCES

1. P. Kundur, “Power System Stability and Control”, McGraw-Hill, 2006.
2. K.R.Padiyar, “HVDC Power Transmission Systems”, New Age International (P)Ltd., NewDelhi, 2002.
3. Mohan Mathur, R., Rajiv. K. Varma, “Thyristor – Based Facts Controllers for Electrical Transmission Systems”, IEEE press and John Wiley& Sons, Inc.
4. K.R.Padiyar,” FACTS Controllers in Power Transmission and Distribution”, New Age International(P) Ltd., Publishers, New Delhi, Reprint 2008.
5. J.Arrillaga, , “High Voltage Direct Current Transmission”, Peter Pregrinus, London, 1983.
6. Erich Uhlmann, “ Power Transmission by Direct Current”, BS Publications,2004.
7. V.K.Sood, HVDC and FACTS controllers – Applications of Static Converters in Power System, APRIL 2004 , Kluwer Academic Publishers.
8. A.T.John, “Flexible AC Transmission System”, Institution of Electrical and Electronic Engineers (IEEE), 1999.
9. NarainG.Hingorani, Laszio. Gyugyl, “Understanding FACTS Concepts and Technology of Flexible AC Transmission System”, Standard Publishers, Delhi 2001.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	3	2	-	3
CO2	3	1	3	2	2	3
CO3	3	1	3	3	2	3
CO4	3	2	3	3	2	3
CO5	3	2	3	2	2	3
Average	**2.6**	**1.5**	**3**	**2.4**	**2**	**3**

PS3252 **SMART GRID** **L T P C**
3 0 0 3

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, National and International Initiatives in Smart Grid.

UNIT II SMART GRID TECHNOLOGIES (TRANSMISSION) 9

Technology Drivers, Smart energy resources, Smart substations, Substation Automation, Feeder Automation, Transmission systems: EMS, FACTS and HVDC, Wide area monitoring, Protection and control

UNIT III SMART GRID TECHNOLOGIES (DISTRIBUTION) 9

DMS, Volt/VAr control, Fault Detection, Isolation and service restoration, Outage management, High-Efficiency Distribution Transformers, Phase Shifting Transformers, and Plug in Hybrid Electric Vehicles (PHEV).

UNIT IV 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), Intelligent Electronic Devices (IED) & their application for monitoring & protection.

UNIT V COMMUNICATION PROTOCOLS FOR POWER SYSTEM AUTOMATION 9

Introduction to Communication Protocol, Comparison of Communication media and different communication network topologies Description of Different Communication Protocol - Physical based Protocol(RS-232,RS-485) - Layered Based Protocol(IEC-61850 - Substation Automation) (C37.118 - Wide Area Monitoring and Protection),(DNP3 - Distribution Automation),MODBUS.

TOTAL: 45 PERIODS

COURSE OUTCOMES

Students will be able to:

CO1:Understand on the concepts of Smart Grid and its present developments.
CO2:Analyze about different Smart Grid transmission technologies.
CO3:Analyze about different Smart Grid distribution technologies.
CO4:Acquire knowledge about different smart meters and advanced metering infrastructure.
CO5:Develop more understanding on LAN, WAN and Cloud Computing for Smart Grid applications.

REFERENCES

1. Stuart Borlase "Smart Grid :Infrastructure, Technology and Solutions",CRC Press 2016.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, "Smart Grid: Technology and Applications",Wiley.
3. Vehbi C. Gungor, DilanSahin, TaskinKocak, SalihErgut, ConcettinaBuccella, Carlo Cecati ,and Gerhard P. Hancke, Smart Grid Technologies: Communication Technologies and Standards IEEE Transactions On Industrial Informatics, Vol. 7, No. 4, November 2011.
4. Xi Fang, SatyajayantMisra, GuoliangXue, and Dejun Yang "Smart Grid – The New and Improved Power Grid: A Survey" , IEEE Transaction on Smart Grid

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	-	1	-	-
CO2	1	2	-	1	1	1
CO3	1	2	-	1	2	-
CO4	1	-	-	1	1	2
CO5	1	2	2	1	-	2
Average	**1**	**2**	**2**	**1**	**1.33**	**1.67**

PS3054 WIND ENERGY CONVERSION SYSTEMS **L T P C**
3 0 0 3

UNITI INTRODUCTION 9
Components of WECS-WECS schemes-Power obtained from wind-simple momentum theory- Power coefficient-Sabinin's theory-Aerodynamics of Wind turbine

UNIT II WINDTURBINES 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 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 modelling - Variable speed variable frequency schemes.

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
Students will be able to:
CO1: Attain knowledge on the basic concepts of Wind energy conversion system.
CO2: Attain the knowledge of the mathematical modelling 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 modelling.

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

REFERENCES

1. L.L.Freris "Wind Energy conversion Systems", Prentice Hall,1990
2. S.N.Bhadra, D.Kastha,S.Banerjee, "Wind Electrical Systems", Oxford University Press,2010.
3. Ion Boldea, "Variable speed generators", Taylor & Francis group,2006.
4. E.W.Golding "The generation of Electricity by wind power", Redwood burn Ltd., Trowbridge,1976.
5. N. Jenkins," Wind Energy Technology" John Wiley &Sons,1997.
6. S.Heir "Grid Integration of WECS", Wiley1998.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	2	2	-	2
CO2	3	1	2	2	2	2
CO3	3	1	3	3	2	3
CO4	3	2	3	3	2	3
CO5	3	2	3	2	2	3
Average	**2.6**	**1.5**	**2.2**	**2.4**	**2**	**2.2**

PS3053 OPTIMIZATION TECHNIQUES TO POWER SYSTEM ENGINEERING L T P C
3 0 0 3

UNIT I CLASSICAL OPTIMIZATION TECHNIQUES 9

Historical Development, Engineering Applications of Optimization, Statement of Optimization Problem. Single variable optimization, Multivariable optimization with no constraints; Multivariable optimization with Equality constraints – Solution by Direct Substitution method, Method of constrained variation, Method of Lagrangian multipliers; Multivariable optimization with inequality constraints: Kuhn-Tucker conditions – solution of economic dispatch problem.

UNIT II LINEAR PROGRAMMING 9

Introduction, Applications of Linear Programming, Standard Form of a Linear Programming, Basic Terminology and Definitions, Exceptional cases, Simplex method, Revised Simplex method, Duality.

UNIT III NONLINEAR 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 – solution of unit commitment problem.

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, global optimization using GA, Applications to power system problems.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

CO1: learn about different classifications of optimization problems and classical optimization techniques.

CO2: analyze linear programming problems

CO3: analyze non-linear programming problems

CO4: explain the concepts of dynamic programming

CO5: explain Genetic algorithm and its application to power system optimization problems.

REFERENCES:

1. SingiresuS. Rao, “Engineering Optimization – Theory and Applications”, Third Edition, John Wiley & Sons, Inc., 1996.
2. Luenberger G., “Introduction of Linear and Non-Linear Programming”, Wesley Publishing Company, 2011.
3. Taha, H.A., “Operations Research—an Introduction”, Tenth Edition, Pearson Education, 2019.
4. Vohra, N.D., “Quantitative Techniques in Management”, Fifth Edition, Tata McGraw-Hill Education, 2017.
5. Rardin, R.L., “Optimization in operations research: Upper Saddle River”, Second Edition, Pearson, 2017.
6. Kothari, D.P. and Dhillon, J.S., “Power system optimization”, Second Edition, PHI Learning Private Limited, 2010.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	-	1	-	-
CO2	2	-	-	1	-	-
CO3	2	-	-	1	-	-
CO4	2	-	-	1	-	-
CO5	2	-	-	1	-	-
Average	**2**	-	-	**1**	-	-

PW3052 ELECTRIC VEHICLES AND POWER MANAGEMENT **LT P C**
3 0 0 3

UNIT I HYBRID ELECTRIC VEHICLE ARCHITECTURE AND POWER TRAIN COMPONENTS 9
History of Evolution of Electric Vehicles (EV) - Comparison of Electric Vehicles with Internal Combustion Engines - Architecture of Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV) – Plug-in Hybrid Electric Vehicles (PHEV)- Power Train Components and Sizing, Gears, Clutches, Transmission and Brakes

UNIT II MECHANICS OF HYBRID ELECTRIC VEHICLES 9
Fundamentals of Vehicle Mechanics - Tractive Force, Power and Energy Requirements for Standard Drive Cycles of HEV's - Motor Torque - Power Rating and Battery Capacity

UNIT III CONTROL OF DC AND AC MOTOR DRIVES 9
Speed control for Constant Torque, Constant HP operation of all Electric Motors - DC/DC chopper based Four Quadrant Operation of DC Motor Drives, Inverter-based V/f Operation (motoring and braking) of Induction Motor Drives, Vector Control Operation of Induction Motor and PMSM, Brushless DC Motor Drives, Switched Reluctance Motor (SRM) Drives

UNIT IV ENERGY STORAGE SYSTEMS 9
Battery: Principle of operation, Types, Estimation Of Parameters, Battery Modeling, SOC of Battery, Traction Batteries and their capacity for Standard Drive Cycles, Vehicle to Grid operation of EV's - Alternate sources: Fuel cells, Ultra capacitors, Fly wheels

UNIT V HYBRID VEHICLE CONTROL STRATEGY AND ENERGY MANAGEMENT 9
HEV Supervisory Control - Selection of modes - Power Spilt Mode - Parallel Mode - Engine Brake Mode - Regeneration Mode - Series Parallel Mode - Energy Management of HEV's

TOTAL: 45 PERIODS

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

CO1: Learn the electric vehicle architecture and power train components.
CO2: Acquire the concepts of dynamics of Electrical Vehicles.
CO3: Understand the vehicle control for Standard Drive Cycles of Hybrid Electrical Vehicles (HEVs).
CO4: Ability to model and understand the Energy Storage Systems for EV.
CO5: Acquire the knowledge of different modes and Energy Management in HEVs.

REFERENCES:

1. Iqbal Husain, “Electric and Hybrid Electric Vehicles”, First Edition, CRC Press, 2011
2. Wei Liu, “Hybrid Electric Vehicle System Modeling and Control”, Second Edition, Wiley, 2017
3. James Larminie and John Lowry, “Electric Vehicle Technology Explained”, Second Edition, 2012
4. Mehredad Ehsani, Yimi Gao, Stefano Longo and Kambiz Ebrahimi,” Modern Electric, Hybrid Electric and Fuel cell Vehicles”, Third edition, CRC Press, 2019
5. Jingsheng Yu and Vladimir V. Vantsevich, “Control Application of Vehicle Dynamics”, First Edition, CRC Press, 2021

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	1	-	3
CO2	3	1	2	1	-	3
CO3	3	1	2	1	-	3
CO4	3	1	2	1	-	3
CO5	3	1	2	1	-	3
Average	**3**	**1**	**2**	**1**	**-**	**3**

PW3151 ELECTRIC VEHICLE CHARGING INFRASTRUCTURE **L T P C**
3 0 0 3

UNIT I INTRODUCTION 9

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

UNIT II BUSINESS MODEL AND ELECTRICITY TARIFF STRUCTURE 9

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

UNIT III ELECTRIC DISTRIBUTION SYSTEM FOR FAST CHARGING INFRASTRUCTURE 9

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

UNIT IV POWER QUALITY AND EMI/EMC CONSIDERATIONS 9

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

UNIT V ENERGY STORAGE SYSTEMS 9

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

TOTAL: 45 PERIODS

COURSE OUTCOMES:
Upon the successful completion of the course, students will be able to:
CO1: Design and select AC and DC chargers.
CO2: Understand and create awareness about power purchase and its tariff policy and its regulations.
CO3: Design a fast-charging infrastructure in a distribution network.
CO4: Understand the consequences of power quality issues and EMI/EMC in power grid.
CO5: Analyze the need for ESS in EVSE and ESS integrated to the microgrid.

REFERENCES:

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

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	-	2	3
CO2	3	1	1	-	2	3
CO3	3	1	1	-	2	3
CO4	3	1	1	-	2	3
CO5	3	1	1	-	2	3
Average	**3**	**1**	**1**	**-**	**2**	**3**

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PW3251 **ENERGY STORAGE SYSTEMS** **LT P C**
3 0 0 3

UNIT I INTRODUCTION 9
Necessity for Energy Storage – Types of Energy Storage – Comparison of Energy Storage Technologies – Applications

UNIT II MECHANICAL ENERGY STORAGE SYSTEM 9
Overview - Pumped Hydroelectric Storage (PHS) – Compressed-Air Energy Storage (CAES) – Various CAES – Flywheel Energy Storage (FES) – Comparison of PHS, CAES and FES

UNIT III ELECTROCHEMICAL ENERGY STORAGE 9
Fundamental concept of Batteries – measuring the battery performance, charging and Discharging of a battery, Power Density - Energy Density – C-Rate – Spider Diagram of Battery- Battery Energy Storage Systems (BESS) – Lead Acid Battery - Nickel – Cadmium Batteries - Lithium-ion Batteries – High Temperature Batteries – Metal – Air Batteries - Flow Batteries

UNIT IV FUEL CELL 9
History of Fuel Cell – Construction - Working Principle of Fuel Cell – Types – Hydrogen Fuel cells, Proton Exchange Membrane Fuel Cell, Solid Oxide Fuel Cell – Advantages and Disadvantages

UNIT V ALTERNATE ENERGY STORAGE TECHNOLOGIES 9
Super capacitors, Principle – Applications, Superconducting Magnetic Energy Storage - Concept of Hybrid Storage – Applications, - Hydrogen Production - Hydrogen Storage Technologies - Safety and Management of Hydrogen Storage – Power to Gas Technology (P2G)

TOTAL: 45 PERIODS

COURSE OUTCOMES:
Upon the successful completion of the course, students will be able to:
CO1: Gained knowledge of various storage technologies
CO2: Understand the mechanical storage system
CO3: Do performance analysis of Various Battery Energy Storage System
CO4: Analyze the operation of fuel cell
CO5: Gain Knowledge on various types of alternate storage technologies and perform the selection based on techno-economic viewpoint.

REFERENCES:

1. David Linden, Thomas B.Reddy, "Handbook of Batteries", Third Edition, Tata Mc-Graw Hill, 2002.
2. James Larminie, Andrew Dicks, "Fuel cell Systems Explained", Third Edition, Wiley, 2018.
3. Ru-Shi Liu, Lei Zhang and Xueliang Sun, "Electrochemical Technologies for Energy Storage and Conversion", First Edition, Wiley, 2012.
4. P.Jayarama Reddy, "Principles of Energy Storage Systems", BS Publications, Hyderabad, First Edition, 2022.
5. G.D.Rai, "Non-Conventional Energy Sources", VI Edition Khanna Publishes, First Edition, 2017.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	-	1	2
CO2	2	1	3	-	1	2
CO3	2	1	3	-	1	2
CO4	2	1	3	-	1	2
CO5	2	1	3	-	1	2
Average	**2**	**1**	**3**	**-**	**1**	**2**

PW3051 DESIGN AND MODELLING OF SOLAR PV SYSYTEMS LT P C
3 0 0 3

UNIT I SOLAR PV SYSTEMS OVERVIEW 9

Introduction to Solar PV systems – Solar PV modules and its types -Types of PV systems: Grid Connected and Standalone – Inverter and its types: string inverter, central inverter, micro inverter – Charge Controller - MPPT – I-V curve – P-V curve - tilt angle – azimuth angle – Standard Test Conditions (STC)

UNIT II GRID-CONNECTED PHOTOVOLTAIC SYSTEMS 9

Introduction – Types: Rooftop Solar PV systems, Ground Mounted Solar PV systems and Floating Solar PV systems – Single Line Diagram - Balance Of Plant (BOP) - String Sizing - Power and Energy Losses - Temperature and Shading Effects - Power Plant Controller (PPC) – Grounding: IEEE 2778-2020 – Levelized Cost Of Energy Analysis (LCOE) – Power Evacuation- Net Metering

UNIT III STANDALONE SOLAR PV SYSTEMS 9

Introduction—Design Methodology for Standalone SPV systems — Need for Balance Of System (BOS) – Batteries for SPV system– Installation, Trouble Shooting and Safety

UNIT IV ENERGY ESTIMATION 9

Introduction - Energy estimation for Grid Connected PV systems using PVsyst – Energy Estimation for standalone PV systems using PVsyst – Energy losses: Array Incidence Losses, Incidence Angle Modifier (IAM), ohmic losses, Module Quality Loss, Module Mismatch Loss, Soiling Loss, Light Induced Degradation (LID), module degradation loss, connection loss, system availability loss, Potential-Induced Degradation (PID), inverter loss, inverter clipping loss – Performance Ratio (PR) – Capacity Utilization Factor (CUF)

UNIT V GRID CODE REQUIREMENTS AND STANDARDS **9**

CEA Technical Standard for Connectivity to the Grid: Voltage, Frequency, LVRT, HVRT, Power Factor, Harmonics, DC Injection, Voltage Flicker – IEEE 2800- 2022: Q vs P and Q vs V, Reactive Power Capability, Power Quality, Protection, Low and High Voltage Ride Through – Low and High Frequency Ride Through

TOTAL = 45 PERIODS

COURSE OUTCOMES:

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

CO1: Review the perspectives of solar PV systems and its types
CO2: Understand various types of Grid Connected Solar PV system and SPV plant grounding
CO3: Study the various aspects of standalone solar PV systems
CO4: Perform Energy estimation of grid connected and standalone solar PV system
CO5: Understand Technical requirements of grid codes and standards for interconnection

REFERENCES:

1. Suneel Deambi, “Photovoltaic System Design”, 1st edition, CRC press, 2016.
2. John Bailfour, Michael Shaw, Nicole Bremer Nash, “Introduction to Photovoltaic System Design”, 1st edition, Jones & Bartlett Learning, 2011.
3. Marco Rosa-Clot, Giuseppe Marco Tina, “Floating PV Plants”, 1st edition, Academic Press, 2020.
4. John Bailfour, Michael Shaw, Nicole Bremer Nash, “Advanced Photovoltaic System Design”, 1st edition, Jones & Bartlett Learning, 2011.
5. N.D. Kaushika, Anuradha Mishra, Anil K. Rai, “Solar Photovoltaics Technology, System Design, Reliability and viability”, 1st edition, Springer, 2018.
6. Sanjeevikumar P, Sharmeela C, Jens Bo Holm-Nielsen, Sivaraman P, “Power quality in modern power systems”, 1st edition, Academic Press, 2020.
7. Rabindra Kumar Satpathy, Venkateswarlu Pamuru, “Solar PV Power”, 1st edition, Academic Press, 2020.
8. Chetan Singh Solanki, “Solar Photovoltaic Technology and Systems” – A Manual for Technicians, Trainees and Engineers, PHI, 2014.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	2	1	-
CO2	3	1	2	2	1	-
CO3	3	1	2	2	1	-
CO4	3	1	2	2	1	-
CO5	3	1	2	2	1	-
Average	**3**	**1**	**2**	**2**	**1**	**-**

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PW3054 GRID INTEGRATION OF RENEWABLE ENERGY SOURCES **L T P C**
3 0 0 3

UNIT I INTRODUCTION 9

Introduction to Renewable Energy (RE) based grid integration - Concept of mini/micro/nano grids and Smart grids - Different types of grid interfaces - Issues related to grid integration of small and large scale of synchronous generator based - induction generator based and converter-based sources together - Influence of WECS on system transient response – Technical and Economic Aspects of Grid Integration of RES

UNIT II NETWORK INFLUENCE OF GENERATION TYPE 9

Interconnection standards and grid code requirements for grid integration – starting – Network voltage management – Thermal/Active Power management – Network power quality management – Transient system performance – Fault level issues –Low Voltage Fault Ride Through (LVRT) – Protection – Study of Blackouts and Brownouts – Causes, effects and mitigation

UNIT III GRID INTEGRATION OF WIND POWER 9

Introduction-Electric Grid- Embedded Generation- Functional Requirements of Wind Power Plant (WPP) in Electric Grid- Types of WPP and Wind Farm Grid Connections - Interface Issues - Operational Issues: Power System Stability, Frequency Control, Short Term Balancing, Long Term Balancing, Transmission and Distribution System Impacts, Economic Dispatch and Unit Commitment – Sitting WPPs for Effective Grid Integration - Grid Integration issues in India – Challenges for Grid Integration – Wind Power Integration Standards – Super Grid Strategy

UNIT IV GRID- CONNECTED SPV SYSTEM 9

Introduction- Configurations-Components of Grid-connected SPV system– Grid-connected PV System Design: Small Power Applications and Power Plants–Safety in installation of SPV system– Installation and troubleshooting of SPV power plants - International PV programs

UNIT V GRID CODE COMPLIANCE AND GRID INTEGRATION STANDARDS 9

IEC TS 63102-2021: Compliance assessment methods – Operating area – Control performance – Fault ride through – Power Quality – IEEE standards: IEEE 2800-2022, IEEE 1547-2018- CEA standards: technical standards for connectivity to grid, Distributed Energy Resources- RE Policies and Regulations in India

TOTAL = 45 PERIODS

COURSE OUTCOMES:

Upon completion of the course, students will be able to:
CO1: Know about the integration of various renewable energy sources into the grid.
CO2: Analyze various grid issues due to renewable energy sources.
CO3: Analyze and understand the grid-connected WPP.
CO4: Design the grid connected SPV system.
CO5: Understand about the various grid interconnection standards and grid code compliance

REFERENCES:

1. Joshua Earnest, “Wind power technology”, II Edition, PHI, 2015.
2. Brenden Fox, Damian Flynn and Leslie Bryans, “Wind Power Integration Connection and system operational aspects”, The Institute of Engineering and Technology, London, United Kingdom, 2007.
3. Chetan Singh Solanki, “Solar Photovoltaic Technology and Systems” – A Manual for Technicians, Trainees and Engineers, PHI, 2014.
4. Stuart R.Wenham, Martin A. Green, Muriel E. Watt and Richard Corkish, “Applied Photovoltaics”, Earthscan, UK, 2007.
5. Heier, Siegfried, “Grid Integration of Wind Energy Conversion Systems”, Germany, Wiley, 2006.
6. Joshua Earnest, Tore Wizelius, “Wind Power Plants and Project Development”, Second Edition, PHI learning, 2017.
7. IEC TS 63102:2021 Grid code assessment methods for grid connection of wind and PV power plants
8. CEA technical standards for connectivity to the grid
9. CEA technical standards for connectivity of the distributed generation resources
10. IEEE Std 2800-2022 IEEE standard for interconnection and interoperability of inverter-based resources (IBRS) interconnecting with associated transmission electric power systems
11. IEEE Std 1547-2018 IEEE standard for interconnection and interoperability of distributed energy resources with associated electric power systems interface.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	1	2	-
CO2	3	1	2	1	2	-
CO3	3	1	2	1	2	-
CO4	3	1	2	1	2	-
CO5	3	1	2	1	2	-
Average	**3**	**1**	**2**	**1**	**2**	**-**

CO3151 **CONTROL SYSTEM DESIGN** **LT P C**
4 0 0 4

UNIT I ANALYSIS OF LINEAR SYSTEMS 12

Review of system models –Transfer function and state space form– Time and Frequency Response – stability- Discretization –Need for Discretization –Sample and Hold devices – Effect of sampling on transfer function and state models – Analysis – Test for controllabilityand Observability.

UNIT II DESIGN OF SISO SYSTEM 12

Design Specifications –In continuous domain – Limitations – Controller Structure – Multiple degrees of freedom – PID controllers and Lag-lead compensators- Design – Discretization and direct discrete design - Design in continuous and discrete domain

UNIT III STATE SPACE DESIGN 12

Pole assignment design – State and Output Feedback – observers – Estimated State Feedback – Design Examples (Continuous and Discrete).

UNIT IV OPTIMAL CONTROL 12

Introduction: Classical control and optimization, formulation of optimal control problem, Typical performance measures – Linear quadratic regulator problem – solution – Applicationexamples.

UNIT V OPTIMAL FILTERING 12

Filtering – Linear system and estimation – System noise smoothing and prediction – Kalman Filter –Recursive estimation.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

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

CO1 Analyse controllers for linear systems defined in transfer function and state space forms.
CO2 Design controllers for linear systems defined in transfer function and state space forms.
CO3 Apply state space forms to continuous and discrete systems.
CO4 Apply optimal control to linear systems in continuous and discrete systems
CO5 Apply filtering concepts to linear systems in continuous and discrete systems.

TEXT BOOKS:

1. M.Gopal, "Digital Control and State Variable Methods", 4th edition, McGraw Hill India, 2012
2. K. Ogata, 'Modern Control Engineering', 5th Edition, Pearson, 2012.
3. K. P. Mohandas, "Modern Control Engineering", Sanguine Technical Publishers, 2006.
4. Kirk D.E., 'Optimal Control Theory – An introduction', Prentice
5. hall, N.J., 1970.
6. Sage, A.P., 'Optimum System Control', Prentice Hall N.H., 1968.
7. Anderson, BD.O. and Moore J.B., 'Optimal Filtering', Prentice hall Inc., N.J., 1979.

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REFERENCES:

1. M.Gopal, Modern Control System Theory, 3rd edition, New Age InternationalPublishers, 2014.
2. William S Levine, “Control System Fundamentals,” The Control Handbook, CRCPress, Taylor and Francis Group, 2011.
3. AshishTewari, ‘Modern Control Design with Matlab and Simulink’, John Wiley, NewDelhi, 2002.
4. T. Glad and L. Ljung, “Control Theory –Multivariable and Non-Linear Methods”,Taylor & Francis, 2002.
5. M. Chidambaram and R. Padma Sree, “Control of Unstable Single and Multi-Variable Systems”, Narosa Publishing, 2017.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	-	-	3	3	2	2
CO2	-	-	-	3	2	2
CO3	3	-	3	3	3	2
CO4	3	2	3	3	2	3
CO5	2	3	2	3	3	3
Avg.	2.6	2.5	2.75	3	2.4	2.4

Note: 1-low, 2-medium, 3-high, ‘-“- no correlation

CO3152 **INTELLIGENT CONTROLLERS** **LT P C**
3 0 0 3

UNIT I OVERVIEW OF ARTIFICIAL NEURAL NETWORK (ANN) & FUZZY LOGIC **9**

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

UNIT II NEURAL NETWORKS FOR MODELLING AND CONTROL **9**

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

UNIT III FUZZY LOGIC FOR MODELLING AND CONTROL **9**

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

UNIT IV GENETIC ALGORITHM **9**

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

UNIT V HYBRID CONTROL SCHEMES **9**

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

TOTAL: 45 PERIODS

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

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

REFERENCES:

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

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	-	2	1	-	-	-
CO2	-	2	1	-	-	-
CO3	-	1	-	-	-	-
CO4	3	2	-	2	-	-
CO5	-	1	-	1	1	3
Average	**3**	**1.6**	**1**	**1.5**	**1**	**3**

Note: 1-low, 2-medium, 3-high, '-"- no correlation

CO3252 **NON LINEAR CONTROL** **L T P C**
3 1 0 4

UNIT I PHASE PLANE ANALYSIS 9+3

Concepts of phase plane analysis- Phase portraits- singular points- Symmetry in phase planeportraits- Constructing Phase Portraits- Phase plane Analysis of Linear and Nonlinear Systems- Existence of LimitCycles. Analysis using computer simulations

UNIT II DESCRIBING FUNCTION 9+3

Describing Function: Fundamentals – Definitions – Assumptions - Computing Describing Functions - Common Nonlinearities and its Describing Functions - Nyquist Criterion and its Extension- Existence of Limit Cycles-Stability of limit Cycles. Analysis using computer simulations

UNIT III LYAPUNOV THEORY 9+3

Nonlinear Systems and Equilibrium Points - Concepts of Stability - Linearization and LocalStability - Lyapunov's Direct Method - Lyapunov Functions – construction - - Control Design based on Lyapunov's Direct Method. Analysis using computer simulations

UNIT IV FEEDBACK LINEARIZATION 9+3

Feedback Linearization and the Canonical Form - Mathematical Tools - Input-State Linearization of SISO Systems – input - Output Linearization of SISO Systems - Generating a Linear Input-Output Relation - Normal Forms - The Zero Dynamics - Stabilization and Tracking - Inverse Dynamics and Non Minimum Phase Systems-Feedback Linearization of MIMO Systems Zero-Dynamics and Control Design. Analysis using computer simulations

UNIT V SLIDING MODE CONTROL 9+3

Sliding Surfaces - Continuous approximations of Switching Control laws - The Modeling / Performance Trade-Offs- MIMO Systems. Analysis using computer simulations

L: 45 + T: 15 TOTAL: 60 PERIODS

COURSE OUTCOMES:

Ability to

CO1 :Analyse system performance in the presence of control non-linearity

CO2 :Analyse system performance using describing function method

CO3 :Analyse non-linear system performance by constructing Lyapunov function

CO4 :Analyse and Design robust controllers for non-linear systems for parameter variations butwith stable zero-dynamics.

CO5 : Implement controllers for MIMO systems using computer simulations

REFERENCES:

1. J A E Slotine and W Li, Applied Nonlinear control, PHI, 1991.
2. K. P. Mohandas, Modern Control Engineering, Sanguine, India, 2006
3. Hasan Khalil, “Nonlinear systems and control”, Prentice Hall.
4. S H Zak, “Systems and control”, Oxford University Press, 2003.
5. Torkel Glad and Lennart Ljung, “Control Theory – Multivariable and Nonlinear Methods”, Taylor& Francis, 2002.
6. G. J. Thaler, “Automatic control systems”, Jaico publishers, 2006.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	3
CO2	3	1	2	3	3	2
CO3	3	2	2	3	3	2
CO4	3	3	3	3	3	2
CO5	3	3	3	3	2	2
AVg.	**3**	**2**	**2.6**	**3**	**2.8**	**2.2**

Note: 1-low, 2-medium, 3-high, ‘-“- no correlation

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CO3055 **MODEL PREDICTIVE CONTROL** **L T P C**
3 0 0 3

UNIT I INTRODUCTION 9
Models for MPC-Linear Dynamic Models, Input-Output Models, Distributed Models, Constraints and Unconstrained model.

UNIT II MODEL ANALYSIS AND DISTURBANCE MODELING 9
Model stability; Observability and controllability Representing uncertainty; White, colored and integrating noise

UNIT III STATE ESTIMATION AND MULTIVARIABLE MPC 9
State observer; Pole placement; Stability; Kalman Filter; Stochastic filtering theory; Multivariate MPC.

UNIT IV CONSTRAINED AND UNCONSTRAINED LQ CONTROL 9
Constrained LQ-Time variant and Invariant case: Estimation, control and output; Unconstrained LQ control; Nonlinear Constrained system

UNIT V STATE-SPACE MPC AND CASE STUDIES 9
State-space MPC; deterministic formulation; state feedback control, State-Space Output-Feedback MPC-separation principle; Implementation of output feedback MPC; MPC-Applications : solar power plant.

TOTAL: 45 PERIODS

REFERENCES

1. J.B. Rawlings, D.Q. Mayne and M.M. Diehl (2018) Model Predictive Control: Theory, Computation, and Design, Nobb Hill.
2. E.F. Camacho and C. Bordons (2007) Model Predictive Control, Springer.

COURSE OUTCOMES:
CO1 :Ability to understand the concepts of developing various models for a physical system.
CO2 : Ability to analyze the models and incorporate the uncertainties.
CO3 :Ability to comprehend State Estimation And Multivariable MPC
CO4 :Ability to understand the design of Linear Quadratic control techniques and state space MPC
CO5 : Ability to design a model predictive controller to various applications

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	1	1
CO2	3	3	3	3	1	1
CO3	3	3	3	3	1	1
CO4	3	3	3	3	1	1
CO5	3	3	3	3	1	1
Average	**3**	**3**	**3**	**3**	**1**	**1**

Note: 1-low, 2-medium, 3-high, '- '- no correlation

CO3058 **SYSTEM THEORY** **LT P C**
3 0 0 3

UNIT I STATE VARIABLE REPRESENTATION 9

Introduction-Concept of State-State equation for Dynamic Systems -Time invariance and linearity- Non uniqueness of state model-State Diagrams - Physical System and State Assignment.

UNIT II SOLUTION OF STATE EQUATIONS 9

Existence and uniqueness of solutions to Continuous-time state equations-Solution of Nonlinear and Linear Time Varying State equations-Evaluation of matrix exponential-System modes- Role of Eigenvalues and Eigenvectors.

UNIT III CONTROLLABILITY AND OBSERVABILITY 9

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

UNIT IV STABILTY 9

Introduction-Equilibrium Points-Stability in the sense of Lyapunov-BIBO Stability-Stability of LTI Systems-Equilibrium Stability of Nonlinear Continuous Time Autonomous Systems-The Direct Method of Lyapunov and the Linear Continuous-Time Autonomous Systems-Finding Lyapunov Functions for Nonlinear Continuous Time Autonomous Systems-Krasovskii and Variable-Gradiant Method.

UNIT V MODAL CONTROL 9

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

TOTAL : 45 PERIODS

COURSE OUTCOMES

CO1 :To understand the concept of State-State equation for Dynamic Systems andthe uniqueness of state model.
CO2 :To understand the concept of the uniqueness of state model.
CO3 :Analyse Controllability and Observability for Time varying and Time invariant case
CO4 :Analyse the linear systems in state space
CO5 :Design controllers in state space

REFERENCES:

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

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	-	1	-	-	-	-
CO2	1	-	1	-	-	-
CO3	3	3	3	-	-	-
CO4	-	-	1	3	-	-
CO5	-	-	-	-	-	-
Average	**2**	**2**	**1.6**	**3**	**-**	**-**

Note: 1-low, 2-medium, 3-high, '-"- no correlation

CO3053 INDUSTRIAL INTERNET Of THINGS

L	T	P	C
3	0	0	3

UNIT I INTERNET PRINCIPLES 9

Definition and Characteristics - IoT enabling technologies — Levels of deployment — Domain specific IoTs - SDN and NFV for IoT — ISO/OSI model — MAC address and IP address - Overview of TCP/IP and UDP -Basics of DNS - Classes of IP addresses - Static and dynamic addressing –Salient features of IPV4 – Specifications of IPV6 and 6LoPAN.

UNIT II PHYSICAL AND LOGICAL DESIGN METHODOLOGIES 9

Requirements and Specifications – Device and Component Integration —Physical design using prototyping boards - Sensors and actuators, choice of processor, interfacing and networking - Logical Design — Open source platforms - Techniques for writing embedded code - Case studies and examples using Python programming and Arduino/Raspberry Pi prototyping boards
– IoT application development using Wireless Sensor Networks - Single Node Architecture - Hardware Components, Energy Consumption of Sensor Nodes.

UNIT III PROTOCOLS AND CLOUDS FOR IOT 9

Application layer protocols for IoT – MQTT and –Introduction to cloud storage models and communication APIs – Web application framework – Designing a web API – Web services - IoT device management.

UNIT IV INDUSTRIAL IOT AND SECURITY 9

Introduction to the Industrial Internet - Networked Control Systems – Network delay modeling - Architecture and design methodologies for developing IoT application for Networked Control Systems — Example using SCADA system - Software Design

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Concepts - Middleware IIOT platforms- securing the Industrial Internet- Introduction of Industry 4.0.

UNIT V PROCESS DATA ANALYTICS 9

Process analytics - Dimensions for Characterizing process- process Implementation technology Tools and Use Cases- open source and commercial tools for Process analytics-Big data Analytics for process data - Analyzing Big process data problem — Crowdsourcing and Social BPM - Process data management in the cloud.

TOTAL : 45 PERIODS

COURSE OUTCOMES:

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

CO1: Apply the knowledge of Internet principles and protocols to understand the architectureand specifications of a given network

CO2: Design simple IoT applications using prototyping boards

CO3: Select the appropriate protocol for a specific network implementation

CO4: Identify the security level needed for a particular industrial IOT application

CO5: Analyze the process data using cloud based process data management tools

REFERENCES:

1 ArshdeepBahga and Vijay Madisetti, "Internet of Things A Hands-on Approach", Universities Press (India), 2015

2 Alasdair Gilchrist," Industry 4.0:The Industrial Internet of Things", Apress, 2016.

3 Adrian McEwen and Hakim Cassimally, "Designing the Internet of Things", John Wiley &Sons, 2014

4 Francis Dacosta, "Rethinking the Internet of Things", Apress Open, 2014.

5 Beheshti, S.-M.-R., Benatallah, B., Sakr, S., Grigori, D., Motahari-Nezhad, H.R., Barukh, M.C., Gater, A., Ryu, S.H."Process Analytics Concepts and Techniques for Querying andAnalyzing Process Data" Springer International Publishing Switzerland,2016.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	3	3	3
CO2	2	2	-	3	3	2
CO3	3	3	2	1	3	3
CO4	3	-	3	2	2	3
CO5	3	3	3	3	3	3
AVg.	**2.6**	**2.25**	**2.75**	**2.4**	**2.8**	**2.8**

Note: 1-low, 2-medium, 3-high, '-"- no correlation

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ET3054 EMBEDDED CONTROLLERS FOR EV APPLICATIONS **LT P C**
3 0 0 3

UNIT I EMBEDDED SYSTEM AND ELECTRIC VEHICLES ARCHITECTURE 9
Overview of Electric vehicles - Evolution of Electric Vehicles - Definition and types of EV (BEV, HEV, PHEV) - EV Architecture - EV Components and Subsystems - Advantages and challenges of EV - Comparison of EV with Internal Combustion Engine - Emerging trends in EV Technologies- Embedded System Architecture- Open ECU-AUTOSAR.

UNIT II POWERTRAIN CONTROL AND ENERGY MANAGEMENT SYSTEM IN EV 9
Powertrain Components - Powertrain control and Optimization - Embedded Controllers for motor control- ECU for Energy Management system - Battery Management System (BMS) - Battery State of Charge (SoC) Estimation - Energy Consumption Monitoring - Charging Optimization- ECU for Charging.

UNIT III COMMUNICATION AND CONNECTIVITY IN EV 9
Vehicle-to-Vehicle Technology(V2V) - Vehicle-to-Infrastructure(V2I) Technology Communication - Communication Protocol (CAN, LIN, Ethernet, etc.) - Wireless Charging and Communication for EV - Over the air (OTA) Updates and Remote diagnostics in EV.

UNIT IV FAULT MONITORING AND DIAGNOSTICS IN EV 9
Overview of Fault Monitoring and Diagnostics in EV - Fault detection techniques - Fault Monitoring in Electric Powertrain - Fault Monitoring in Charging Infrastructure - On-board Diagnostics (OBD) with self-check mechanisms - Diagnostics and Reporting - Case studies on fault detection, Diagnosis and Resolution

UNIT V SAFETY, SECURITY AND AUTONOMOUS SYSTEMS IN EV 9
Safety Standards and Regulations for EVs - Functional Safety and ISO26262 in EV -Cybersecurity in EVs - Threats and Countermeasures - Antilock Braking system(ABS) -Electronic Stability Control (ESC) - Advanced driver Assistance systems (ADAS) -Autonomous Driving in EVs.

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1: Able to understand the principles and components of electric vehicles, including powertrain systems, energy storage systems, motor controllers, and vehicle dynamics.
CO2: Able to learn about the unique requirements and challenges associated with embedded controllers in EV applications.
CO3: able to learn about hardware platforms, such as microcontrollers and microprocessors, as well as communication protocols and interfaces used for control and monitoring of EV.
CO4: Able to gain hands-on experience in developing embedded control algorithms for various EV systems, including motor control, battery management, regenerative braking, and charging systems.
CO5: able to understand the integration of embedded controllers in autonomous electric vehicles

REFERENCES:

1."Embedded Control Systems for Electric Machines" by Jiming Wang, Shan Chai, and Shuxin Zhou (Published in 2011)
2."Electric and Hybrid Vehicles: Design Fundamentals" by Iqbal Husain (Published in 2013)
3."Electric and Hybrid Vehicles: Power Sources, Models, Sustainability, Infrastructure, and the Market" by Gérard-André Capolino (Published in 2010)
4."Embedded Systems for Electric Vehicles" by Jürgen Valldorf and Wolfgang Gessner (Published in 2011)

5."Power Electronics and Electric Drives for Traction Applications" by Gonzalo Abad, J. Miguel Guerrero, and Juan de la Casa (Published in 2016)

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3
CO2	3	-	-	-	-	-
CO3	3	-	-	-	-	3
CO4	3	3	3	3	3	3
CO5	2	3	3	3	3	3
Average	**2.8**	**3**	**3**	**3**	**3**	**3**

ET3252 EMBEDDED CONTROL FOR ELECTRIC DRIVES LT P C
2 0 2 3

UNIT I INTRODUCTION ELECTRICAL DRIVES 6
Electric drive and its classifications, Four-quadrant drive, Dependence of load torque on various factors, Dynamics of motor-load combination-Solid State Controlled Drives-Machine learning and optimization techniques for electrical drives- IoT for Electrical drives applications.

UNIT II EMBEDDED PROCESSOR 6
Embedded Processor architecture - RTOS - Hardware/software co-design Programming and optimization with SoC processors - control algorithms implementation for power converter.

UNIT III INDUCTION MOTOR CONTROL 6
Types - Speed control methods - PWM techniques- VSI fed three - phase induction motor- Fuzzy logic Based speed control for three phase induction motor - FPGA based three phase induction motor control.

UNIT IV BLDC MOTOR CONTROL 6
Overview of BLDC Motor - Speed control methods - PWM techniques - ARM processor based BDLC motor control - ANN for BLDC Motor control and operation.

UNIT V SRM MOTOR CONTROL 6
Overview of SRM Motor - Speed control methods - PWM techniques - FPGA based SRM motor control - DNN for SRM Motor control and operation.

30 PERIODS

SKILL DEVELOPMENT ACTIVITIES (Hands on laboratory practice / Seminar/ Mini Project/etc)
30 PERIODS

1. Laboratory exercise: Use any System level simulator/MATLAB/open-source platform to give hands-on training on simulation study on Electric drives and control.
   a. Simulation of four quadrant operation and speed control of DC motor
   b. Simulation of 3-phasee inverter.
   c. Simulation of Speed control of Induction motor using any suitable software package.
   d. Simulation of Speed control of BLDC motor using any suitable software package.
   e. Simulation of Speed control of SRM using any suitable software package

2. Seminar: IoT-based Control and Monitoring for DC Motor/ any Electric drives.
3. Mini project.: Any Suitable Embedded processor-based speed control of Motors (DC/IM/BLDC/PMSM/SRM)

TOTAL: 60 PERIODS

COURSE OUTCOMES:

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

CO1: Interpret the significance of embedded control of electrical drives

CO2: Deliver insight into various control strategy for electrical drives.

CO3: Developing knowledge on Machine learning and optimization techniques for motor control.

CO4: Develop embedded system solution for real time application such as Electric vehicles and UAVs.

CO5: Improved Employability and entrepreneurship capacity due to knowledge up gradation on recent trends in embedded system skills required for motor control strategy.

REFERENCES:

1. R.Krishnan, "Electric Motor Drives - Modeling, Analysis and Control", Prentice-Hall of India Pvt. Ltd., New Delhi,2010.
2. Vedam Subramanyam, "Electric Drives - Concepts and Applications", Tata McGraw- Hill publishing company Ltd., New Delhi, 2002
3. K. Venkataratnam, "Special Electrical Machines", Universities Press, 2014.
4. Steve Furber, "ARM system on chip architecture", Addision Wesley,2010.
5. Ron Sass and AnderewG.Schmidt, "Embedded System design with platform FPGAs: Principles and Practices", Elsevier, 2010.
6. Steve Kilts, "Advanced FPGA Design: Architecture, Implementation, and Optimization" Willey, 2007.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	2	-	2	-
CO2	1	1	3	-	-	2
CO3	2	-	-	-	3	-
CO4	1	2	3	1	-	-
CO5	-	-	-	-	3	-
Average	**1.25**	**1.5**	**2.7**	**1**	**2.7**	**2**

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ET3061 MACHINE LEARNING AND DEEP LEARNING **LT P C**
3 0 0 3

UNIT I LEARNING PROBLEMS AND ALGORITHMS 9
Various paradigms of learning problems, Supervised, Semi-supervised and Unsupervised algorithms

UNIT II NEURAL NETWORKS 9
Differences between Biological and Artificial Neural Networks - Typical Architecture, Common Activation Functions, Multi-layer neural network, Linear Separability, Hebb Net, Perceptron, Adaline, Standard Back propagation Training Algorithms for Pattern Association - Hebb rule and Delta rule, Hetero associative, auto associative, Kohonen Self Organising Maps, Examples of Feature Maps, Learning Vector Quantization, Gradient descent, Boltzmann Machine Learning.

UNIT III MACHINE LEARNING - FUNDAMENTALS & FEATURE SELECTIONS & CLASSIFICATIONS 9
Classifying Samples: The confusion matrix, Accuracy, Precision, Recall, F1 - Score, the curse of dimensionality, training, testing, validation, cross validation, overfitting, under-fitting the data, early stopping, regularization, bias and variance. Feature Selection, normalization, dimensionality reduction, Classifiers: KNN, SVM, Decision trees, Naïve Bayes, Binary classification, rain forest algorithm-multi class classification, clustering.

UNIT IV DEEP LEARNING: CONVOLUTIONAL NEURAL NETWORKS 9
Feed forward networks, Activation functions, back propagation in CNN, optimizers, batch normalization, convolution layers, pooling layers, fully connected layers, dropout, case study based on CNNs.

UNIT V DEEP LEARNING: RNNS, AUTOENCODERS AND GANS 9
State, Structure of RNN Cell, LSTM and GRU, Time distributed layers, Generating Text, Autoencoders: Convolutional Autoencoders, Denoising autoencoders, Variational autoencoders, GANs: The discriminator, generator, DCGANs

TOTAL: 45 PERIODS

COURSE OUTCOMES (CO):
At the end of the course the student will be able to
CO1: Illustrate the categorization of machine learning algorithms.
CO2: Compare and contrast the types of neural network architectures, activation functions
CO3: Acquaint with the pattern association using neural networks
CO4: Elaborate various terminologies related with pattern recognition and architectures of convolutional neural networks
CO5: Construct different feature selection and classification techniques and advanced neural network architectures such as RNN, Autoencoders, and GANs.

REFERENCES:

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

5. Understanding Machine Learning. Shai Shalev-Shwartz and Shai Ben-David. Cambridge University Press. 2017.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	3	1	-	-	-
CO2	2	3	2	-	-	-
CO3	3	-	3	-	3	-
CO4	2	3	3	-	-	-
CO5	3	3	3	-	3	-
Average	2.2	3	2.4	-	3	

ET3067 UNMANNED AERIAL VEHICLE LT P C
3 0 0 3

UNIT I INTRODUCTION TO UAV 9
Overview and background - History of UAV -classification - societal impact and future outlook Unmanned Aerial System (UAS) components - models and prototypes - System Composition - Applications

UNIT II THE DESIGN OF UAV SYSTEMS 9
Introduction to Design and Selection of the System- Aerodynamics and Airframe Configurations - Characteristics of Aircraft Types - Design Standards - Regulatories and regulations - Design for Stealth - control surfaces - specifications.

UNIT III HARDWARES FOR UAVs 9
Real time Embedded processors for UAVs – sensors - servos - accelerometer – gyros -actuators - power supply - integration, installation, configuration, and testing - MEMS/NEMS sensors and actuators for UAVs - Autopilot - AGL.

UNIT IV COMMUNICATION PAYLOADS AND CONTROLS 9
Payloads-Telemetry – tracking - Aerial photography - controls - PID feedback- radio control frequency range - modems - memory system – simulation - ground test – analysis - trouble shooting.

UNIT V THE DEVELOPMENT OF UAV SYSTEMS 9
Waypoints navigation - ground control software - System Ground Testing - System In - flight Testing - Mini, Micro and Nano UAVs - Case study: Agriculture- Health- Surveying- Disaster Management and Defense.

TOTAL: 45 PERIODS

COURSE OUTCOMES:
At the end of this course, the students will have the ability in
CO1: Identify different hardware for UAV.
CO2: Determine preliminary design requirements for an unmanned aerial vehicle.
CO3: Design UAV system.

CO4: Identify and Integrate various systems of unmanned aerial vehicle.
CO5: Design micro aerial vehicle systems by considering practical limitations.

REFERENCES:

1. Reg Austin "Unmanned Aircraft Systems UAV design, development and deployment", Wiley, 2010.
2. Paul G Fahlstrom, Thomas J Gleason, "Introduction to UAV Systems", UAV Systems, Inc, 1998
3. Dr. Armand J. Chaput, "Design of Unmanned Air Vehicle Systems", Lockheed Martin Aeronautics Company, 2001
4. Kimon P. Valavanis, "Advances in Unmanned Aerial Vehicles: State of the Art and the Road to Autonomy", Springer, 2007
5. Robert C. Nelson, "Flight Stability and Automatic Control", McGraw-Hill, Inc, 1998.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	3	2	-	-	2
CO2	3	3	3	-	-	2
CO3	3	3	3	3	3	3
CO4	-	-	2	3	3	2
CO5	3	-	3	3	3	3
Average	**2.5**	**3**	**2.6**	**3**	**3**	**2.4**

ET3060 IoT FOR SMART SYSTEMS **L T P C**
3 0 0 3

UNIT I INTRODUCTION TO INTERNET OF THINGS 9

Overview, Hardware and software requirements for IOT, Sensor and actuators, Technology drivers, Business drivers, Data streaming and cloud services tools- Typical IoT applications, Trends and implications.

UNIT II IOT ARCHITECTURE 9

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

UNIT III PROTOCOLS AND WIRELESS TECHNOLOGIES FOR IOT PROTOCOLS 9

NFC, SCADA and RFID, Zigbee MIPI, M-PHY, UniPro, SPMI, SPI, M-PCIe GSM, CDMA, LTE, GPRS, small cell.

Wireless technologies for IoT: WiFi (IEEE 802.11), Bluetooth/Bluetooth Smart, ZigBee/ZigBee Smart, UWB (IEEE 802.15.4), LoWPAN, Proprietary systems - Recent trends.

UNIT IV IOT PROCESSORS 9

Services/Attributes: Big-Data Analytics for IOT, Dependability, Interoperability, Security, Maintainability.

Embedded processors for IOT: Introduction to Python programming - Building IOT with RASPERRY PI and Arduino.

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UNIT V CASE STUDIES 9

Data streaming and cloud services tools Industrial IoT, IoT for Utilities - Home Automation, IOE- Smart Grid, connected vehicles, electric vehicle charging, Environment, Agriculture, Productivity Applications, IoT for Defense - Smart Energy Management system - Smart Sustainable Cities and Smart Buildings.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

CO1: Analyze the concepts of IoT and its present developments.

CO2: Compare and contrast different platforms and infrastructures available for IoT

CO3: Explain different protocols and communication technologies used in IoT

CO4: Analyze the big data analytic and programming of IoT

CO5: Implement IoT solutions for smart applications

REFERENCES:

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

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	1	-	-	-
CO2	-	2	-	-	-	-
CO3	1	2	-	1	3	-
CO4	2		3	3	3	3
CO5	3	2	3	3	3	3
Average	**1.75**	**2**	**2.33**	**2.33**	**3**	**3**

Attested

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ET3152 VLSI DESIGN AND RECONFIGURABLE ARCHITECTURE

	L	T	P	C
	3	0	0	3

UNIT I CMOS BASICS **9**

Moore's Law - MOSFET Scaling, challenges and limits - MOS Transistor Model -Determination of pull up / pull down ratios - CMOS inverter Characteristics CMOS based combinational logic & sequential design - Dynamic CMOS - Transmission Gates - BiCMOS - Low power VLSI

UNIT II CMOS IC FABRICATIONS **9**

Materials - Synthesis - Clean Room - Standards - Design Rules and Layout - CMOS fabrications Process and methods - n-well - p-well - Twin Tub - SOI - BiCMOS

UNIT III ASIC AND RECONFIGURABLE PROCESSOR AND SoC DESIGN **9**

Introduction to ASIC, ASIC design flow - programmable ASICs - PLDs - reconfigurable processor-Architecture - Reconfigurable Computing, SoC Overview, recent trends in Reconfigurable Processor & SoC, Reconfigurable processor based DC motor control.

UNIT IV ANALOG VLSI DESIGN **9**

Introduction to analog VLSI - Design of CMOS 2 stage - 3 stage Op-Amp - High Speed and High frequency op-amps - Super MOS - Analog primitive cells - Neural Chips - Introduction to Reprogrammable Analog Devices.

UNIT V HDL PROGRAMMING **9**

Overview of digital design with HDL, structural, data flow and behavioral modeling concepts- logic synthesis-simulation-Design examples, Ripple carry Adders, Carry Look ahead adders, Multiplier, ALU, Shift Registers, Test Bench.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

CO1: Understand the CMOS Logics and significance.

CO2: Deliver insight into developing CMOS design techniques and IC fabrication methods.

CO3: Explain the need of reconfigurable computing, hardware-software co design and operation of SoC processor.

CO4: Design and development of reprogrammable analog devices and its usage for Embedded applications.

CO5: Illustrate and develop HDL computational processes with improved design strategies.

REFERENCES:

1. Donald G. Givone, "Digital principles and Design", Tata McGraw Hill 2002.
2. Charles H. Roth Jr., "Fundamentals of Logic design", Thomson Learning, 2004.
3. Nurmi, Jari (Ed.) "Processor Design System-On-Chip Computing for ASICs and FPGAs" Springer, 2007.
4. Joao Cardoso, Michael Hübner, "Reconfigurable Computing: From FPGAs to Hardware/Software Codesign" Springer, 2011.
5. Pierre-Emmanuel Gaillardon, Reconfigurable Logic: Architecture, Tools, and Applications, 1st Edition, CRC Press, 2015
6. Mohamed Ismail, TerriFiez, "Analog VLSI Signal and information Processing", McGraw Hill International Editions,1994.
7. William J. Dally / Curtis Harting / Tor M. Aamodt," Digital Design Using VHDL: A Systems Approach, Cambridge University Press,2015.

8. ZainalatsedinNavabi, 'VHDL Analysis and Modelling of Digital Systems', 2n Edition, Tata McGraw Hill, 1998.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	-	-	-	1	-	-
CO2	2	-	2	2	-	-
CO3	-	-	3	3	2	1
CO4	2	-	2	3	1	-
CO5	-	1	1	3	3	1
Average	2	1	2	2.4	2	1

ET3063 PYTHON PROGRAMMING FOR MACHINE LEARNING **LT P C**
3 0 0 3

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, Training a Model, Evaluation of Model, Performance Improvement

Introduction to Python and its significance - Difference between C, C++ and Python Languages; Compiler and Interpreters - Python3 Installation & Running - Basics of Python Programming Syntax: Variable Types, Basic Operators, Reading Input from User - Arrays/List, Dictionary and Set - Conditional Statements - Control Flow and loop control statements

UNIT II PYTHON FUNCTIONS AND PACKAGES 9

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

UNIT III IMPLEMENTATION OF MACHINE LEARNING USING PYTHON 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 - Introduction to SciPy Package & its functions - Python Application of Linear Regression and Polynomial Regression using SciPy - Interpolation, Overfitting and Underfitting concepts & examples using SciPy

UNIT IV 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 scikit-learn - Using scikit-learn, loading a sample dataset, Learning & prediction, interpolation & fitting, Multiclass fitting - Implementation of SVM using Blood Cancer Dataset, Decision Tree using data from csv, Types of Clustering Algorithms & Techniques - K-means Algorithm, Mean Shift Algorithm & Hierarchical Clustering Algorithm - Introduction to Python Visualization using Matplotlib: Plotting 2-dimensional, 3-dimensional graphs; formatting axis values; plotting multiple rows of data in same graph - Implementation of K-means Algorithm and Mean Shift Algorithm using Python

UNIT V INTRODUCTION TO NEURAL NETWORKS AND EMBEDDED MACHINE LEARNING 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 Classification using MNIST Dataset

ML for Embedded Systems: Comparison with conventional ML - Challenges & Methods for Overcoming – TinyML and TensorFlow Lite for Microcontrollers – on-Board AI – ML Edge Devices: Arduino Nano BLE Sense, Google Edge TPU and Intel Movidius

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

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

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

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

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

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

REFERENCES:

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, VahidMirjalili, "Python Machine Learning - Third Edition", Packt, December 2019

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	-	-	2	3	3	-
CO2	3	1	3	-	3	1
CO3	2	1	2	-	3	3
CO4	3	2	3	3	3	3
CO5	-	-	-		3	-
Average	**2.66**	**1.33**	**2.5**	**3**	**3**	**2.33**

ET3062 MEMS AND NEMS TECHNOLOGY LT P C
3 0 0 3

UNIT I INTRODUCTION TO MEMS and NEMS 9
Overview of micro and Nano technologies - Miniaturization significance and advantages -Micro electro mechanical systems and Nano Electro mechanical systems, devices and technologies, Laws of scaling - Survey of materials - Smart Sensors - Applications of MEMS and NEMS.

UNIT II MICRO-MACHINING AND MICROFABRICATION TECHNIQUES 9
Photolithography - material Synthesis techniques - Film deposition - Etching Processes- wafer bonding - Bulk micro machining, silicon surface micro machining - LIGA process.

UNIT III MICRO SENSORS AND MICRO ACTUATORS 9
Transduction mechanisms in different energy domain-Micromachined capacitive, Piezoelectric, piezoresistive and Electromechanical and thermal sensors/actuators and applications

UNIT IV NANOELECTRONICS DEVICES AND NEMS TECHNOLOGY 9
Nano electronics devices and applications – SET– RTD – Memristor – QCA - molecular Electronics - Nano Fabrication techniques - atomic scale precision Engineering- NEMS in measurement, sensing, actuation and systems design.

UNIT V MEMS AND NEMS APPLICATION 9
Micro/Nano Fluids and applications- Bio MEMS- Optical NEMS- Micro and Nano motors-Quantum computing.

TOTAL: 45 PERIODS

COURSE OUTCOMES:
At the end of this course, the students will have the ability to
- CO1: Explain the material properties and the significance of MEMS and NEMS for industrial automation.
- CO2: Demonstrate knowledge delivery on micromachining and micro fabrication.
- CO3: Apply the fabrication mechanism for MEMS sensor and actuators.
- CO4: Apply the concepts of Nano electronics and NEMS to models, simulate and process the sensors and actuators.
- CO5: Improved Employability and entrepreneurship capacity due to knowledge up gradation on MEMS and NEMS technology.

REFERENCES:

1. Chang Liu, “Foundations of MEMS”, Pearson International Edition, 2006.
2. Marc F madou “Fundamentals of micro fabrication” CRC Press 2002 2nd Edition Marc Madou.
3. M.H.Bao “Micromechanical transducers :Pressure sensors, accelerometers and gyroscopes”,Elsevier, Newyork, 2000.
4. Maluf, Nadim “An introduction to Micro Electro-mechanical Systems Engineering” AR Tech house, Boston 2000.
5. Mohamed Gad - el - Hak “MEMS Handbook” Edited CRC Press 2002 2. Sabriesolomon “Sensors Handbook”, Mc Graw Hill 1998.
6. Tai-Ran Hsu, “MEMS and Microsystems: design, manufacture, and Nanoscale”- 2nd Edition, John Wiley & Sons, Inc., Hoboken, New Jersey, 2008
7. Lyshevski, S.E. “Nano- and Micro-Electromechanical Systems: Fundamentals of Nano-and Microengineering “(2nd ed.). CRC Press,2005.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	-	2	-
CO2	3	3	2	-	2	2
CO3	3	3	3	-	2	2
CO4	3	3	3	-	3	2
CO5	3	2	3	2	3	3
Average	**3**	**2.6**	**2.8**	**2**	**2.4**	**2.25**

ET3065 ROBOTICS AND AUTOMATION LT P C
3 0 0 3

UNIT I INTRODUCTION TO ROBOTICS & AUTOMATION 9
Overview of Robotics & Automation - Principles and Strategies of Automation System -Hardware and software for Automation - Embedded Processors for Automation-Different Types of Robots - Various Generations of Robots - Asimov's Laws Of Robotics - Key components of a robot - Design Criteria for Selection of a Robot - Role of embedded system in Robotics and Automation - Recent trends.

UNIT II SENSORS AND DRIVE SYSTEMS 9
Hydraulic, Pneumatic And Electric Drive Systems - Understanding how motor power, current torque, friction co-efficient affect the design of a Robot - Determination of Motor HP and Gearing Ratio - Variable Speed Arrangements. Sensors - Classification based on sensing type (including Optical, Acoustic, Magnetic) - Proximity Sensors - Ranging Sensors - Speed & Displacement Sensing - Tactile Sensors - Vision Sensing - Smart Sensors - MEMS sensors.

UNIT III MANIPULATORS AND GRIPPERS 9
Introduction to Manipulators - Joints and Degrees of Freedom - Construction of Manipulators - Manipulator Dynamics and Force Control - Electronic And Pneumatic Manipulator Control Circuits - End Effectors - Various Types Of Grippers - Design Considerations.

UNIT IV KINEMATICS AND PATH PLANNING 9
Kinematic Equations - Forward and Inverse Kinematics - Solution Of Inverse Kinematics Problem - Jacobian based Velocity Kinematics- Various Path Planning Algorithms - Hill Climbing Techniques - Robot Operating System - Simulation and modeling of a simple Path Planning application.

UNIT V CASE STUDIES 9
Robot Cell Design - Humanoid Robot - Robots in healthcare applications - Robot Machine Interface - Robots in Manufacturing and Non-Manufacturing Applications - Self balancing robots - Micro/nano robots.

TOTAL: 45 PERIODS

COURSE OUTCOMES:
At the end of this course, the students will have the ability to
CO1: Choose suitable embedded boards for robots
CO2: Demonstrate the concepts of robotics & automation and Working of Robot
CO3: Analyze the Function of Sensors and actuators In the Robot
CO4: Develop Program to Use a Robot for a Typical Application
CO5: Apply and improve Employability and entrepreneurship capacity due to knowledge upgradation on Embedded system-based robot development

REFERENCES:

1. Mikell P. Weiss G.M., Nagel R.N., Odraj N.G., "Industrial Robotics", Mc Graw-Hill Singapore, 1996.
2. Ghosh, Control in Robotics and Automation: Sensor Based Integration, Allied Publishers, Chennai, 1998.
3. Deb. S.R., "Robotics Technology And Flexible Automation", John Wiley, USA 1992.
4. Klafter R.D.,Chimielewski T.A., Negin M., "Robotic Engineering - An Integrated Approach", Prentice Hall of India, New Delhi, 1994.
5. Mc Kerrow P.J. "Introduction to Robotics", Addison Wesley, USA, 1991.
6. Issac Asimov "Robot", Ballantine Books, New York, 1986.
7. Barry Leatham - Jones, "Elements of Industrial Robotics" PITMAN Publishing, 1987.
8. MikellP.Groover, Mitchell Weiss, Roger N.Nagel Nicholas G.Odrey, "Industrial Robotics Technology, Programming And Applications ", McGraw Hill Book Company 1986.
9. Fu K.S. Gonzaleaz R.C. And Lee C.S.G., "Robotics Control Sensing, Vision and Intelligence" McGraw Hill International Editions, 1987

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	-	3	-	-
CO2	-	3	-	-	-	-
CO3	-	-	-	-	-	-
CO4	-	-	-	2	3	1
CO5	-	-	2	1	-	3
Average	**1**	**2.5**	**2**	**2**	**3**	**2**

ET3051 BIG DATA ANALYTICS L T P C
3 0 0 3

UNIT I INTRODUCTION TO BIG DATA 9

Introduction to Big Data Platform - Challenges of Conventional Systems - Intelligent data analysis - Nature of Data - Analytic Processes and Tools - Analysis Vs Reporting - Modern Data Analytic Tools- Statistical Concepts: Sampling Distributions - Re-Sampling - Statistical Inference - Prediction Error.

UNIT II SEARCH METHODS AND VISUALIZATION 9

Search by simulated Annealing - Stochastic, Adaptive search by Evaluation - Evaluation Strategies - Genetic Algorithm - Genetic Programming - Visualization - Classification of Visual Data Analysis Techniques - Data Types - Visualization Techniques - Interaction techniques - Specific Visual data analysis Techniques

UNIT III MINING DATA STREAMS 9

Introduction To Streams Concepts - Stream Data Model and Architecture - Stream Computing - Sampling Data in a Stream - Filtering Streams - Counting Distinct Elements in a Stream - Estimating Moments - Counting Oneness in a Window - Decaying Window - Real time Analytics Platform (RTAP) Applications - Case Studies - Real Time Sentiment Analysis, Stock Market Predictions

UNIT IV FRAMEWORKS 9

Map Reduce - Hadoop, Hive, MapR - Sharding - NoSQL Databases - S3 - Hadoop Distributed File Systems - Case Study - Preventing Private Information Inference Attacks on Social Networks - Grand Challenge: Applying Regulatory Science and Big Data to Improve Medical Device Innovation

UNIT V R LANGUAGE 9

Overview, Programming structures: Control statements - Operators -Functions - Environment and scope issues - Recursion - Replacement functions, R data structures: Vectors - Matrices and arrays - Lists - Data frames - Classes, Input/output, String manipulations

TOTAL:45 PERIODS

COURSE OUTCOMES:

CO1: Understand the basics of big data analytics
CO2: Ability to use Hadoop, Map Reduce Framework.
CO3: Ability to identify the areas for applying big data analytics for increasing the business outcome.
CO4: Gain knowledge on R language
CO5: Contextually integrate and correlate large amounts of information to gain faster insights.

REFERENCES:

1. Michael Berthold, David J. Hand, Intelligent Data Analysis, Springer, 2007.
2. Anand Rajaraman and Jeffrey David Ullman, Mining of Massive Datasets, Cambridge University Press, 3rd edition 2020.
3. Norman Matloff, The Art of R Programming: A Tour of Statistical Software Design, No Starch Press, USA, 2011.
4. Bill Franks, Taming the Big Data Tidal Wave: Finding Opportunities in Huge Data Streams with Advanced Analytics, John Wiley & sons, 2012.
5. Glenn J. Myatt, Making Sense of Data, John Wiley & Sons, 2007.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	-	-	2	-	-	-
CO2	1	-	3	2	-	-
CO3	-	-	1	3	1	-
CO4	1	-	-	1	2	-
CO5	-	-	2	-	-	-
Avg.	**1**	**-**	**2**	**2**	**1.5**	**-**

HV3152 | **ELECTROMAGNETIC FIELD COMPUTATION AND MODELLING** | **LT P C 3 0 0 3**

UNIT I INTRODUCTION 9

Review of basic field theory – Maxwell's equations – Constitutive relationships and Continuity equations – Laplace's, Poisson's and Helmholtz's equation – principle of energy conversion – force/torque calculation.

UNIT II BASIC SOLUTION METHODS FOR FIELD EQUATIONS 9

Limitations of the conventional design procedure, need for the field analysis based design, problem definition, boundary conditions, solution by analytical methods-direct integration method – variable separable method – method of images, solution by numerical methods- Finite Difference Method

UNIT III FORMULATION OF FINITE ELEMENT METHOD (FEM) 9

Concept of FEM - Integral Formulation – Energy minimization – Discretization – Shape functions – Stiffness matrix –1D and 2D planar and axial symmetry problems

UNIT IV COMPUTATION USING FEM PACKAGES 9

Elements of FEM package-pre processor, processor, post processor –computation of Electric Field – Energy- Capacitance, Magnetic Field – Linked Flux – Inductance – Force – Torque , Skin effect – Resistance

UNIT V ELECTROMAGNETIC FIELD MODELLING AND ANALYSIS 9

Three phase transmission lines, Magnetic actuators, Transformers, Insulators , Rotating machines.

TOTAL = 45 PERIODS

COURSE OUTCOMES:

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

CO1 explain the concepts of electromagnetic field theory and energy conversion
CO2 formulate and compute Electromagnetic Field problems from Maxwell's equations
CO3 formulate FEM problems from the fundamental concepts
CO4 compute the respective fields and circuit parameters using FEM (post processing)
CO5 check and optimize the design of electrical power equipment

REFERENCES:

1. Matthew. N.O. Sadiku, S.V. Kulkarni, "Elements of Electromagnetics", Seventh Edition, Oxford University Press, Asian Edition 2021
2. Matthew. N.O. Sadiku "Numerical techniques in electromagnetics", Second Edition, CRC Press,2000.
3. Sivaji Chakravorti, " Electric Field Analysis", CRC Press (Taylor & Francis), USA, 2015
4. Nicola Bianchi, "Electrical Machine analysis using Finite Elements", Taylor and Francis Group, CRC Publishers, 2005.
5. S S Rao, " The Finite Element Method in Engineering", Fifth Edition ,Butterworth-heinmann,2010.
6. J.N.Reddy, " An Introduction to the Finite Element Method". Fourth Edition, Mc Graw Hill Publications, 2019.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	-	3	-	2
CO2	2	1	-	3	-	2
CO3	2	1	-	3	-	2
CO4	2	1	1	3	-	3
CO5	2	1	3	3	-	3
Average	**2**	**1**	**2**	**3**	**-**	**2.4**

HV3052 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY LT P C
3 0 0 3

UNIT I INTRODUCTION 9
Definitions of EMI/EMC -Sources of EMI- Inter systems and Intra system- Conducted and radiated interference- Characteristics - Designing for electromagnetic compatibility (EMC)- EMC regulation- typical noise path- EMI predictions and modelling, Methods of eliminating interferences and noise mitigation

UNIT II GROUNDING AND CABLING 9
Cabling- types of cables, mechanism of EMI emission / coupling in cables –capacitive coupling, inductive coupling- shielding to prevent magnetic radiation- shield transfer impedance, Grounding – safety grounds – signal grounds- single point and multipoint ground systems -hybrid grounds- functional ground layout –grounding of cable shields- -guard shields- isolation, neutralizing transformers, shield grounding at high frequencies, digital grounding- Earth measurement Methods

UNIT III BALANCING, FILTERING AND SHIELDING 9
Power supply decoupling- decoupling filters-amplifier filtering –high frequency filtering- EMI filters characteristics of LPF, HPF, BPF, BEF and power line filter design -Choice of capacitors, inductors, transformers and resistors, EMC design components -shielding – near and far fields shielding effectiveness- absorption and reflection loss- magnetic materials as a shield, shield discontinuities, slots and holes, seams and joints, conductive gaskets-windows and coatings - grounding of shields

UNIT IV EMI IN ELEMENTS AND CIRCUITS 9
Electromagnetic emissions, noise from relays and switches, non-linearities in circuits, passive inter modulation, transients in power supply lines, EMI from power electronic equipment, EMI as combination of radiation and conduction

UNIT V ELECTROSTATIC DISCHARGE, STANDARDS AND TESTING TECHNIQUES 9
Static Generation- human body model- static discharges- ESD versus EMC, ESD protection in equipment- standards - FCC requirements – EMI measurements – Open area test site measurements and precautions- Radiated and conducted interference measurements, Control requirements and testing

methods

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1 Ability to understand the types and sources of EMI.
CO2 Ability to understand the needs of grounding and cabling.
CO3 Ability to understand the design concept of filtering and shielding.
CO4 Ability to study the effect of EMI in elements and circuits.
CO5 Ability to know about the effects of electrostatic discharge and testing techniques.

REFERENCES

1. V.P. Kodali, "Engineering Electromagnetic Compatibility", S. Chand, 1996.
2. Henry W.Ott, " Noise reduction techniques in electronic systems", John Wiley & Sons, 1989.
3. Bernhard Keiser, "Principles of Electro-magnetic Compatibility", Artech House, Inc. (685 canton street, Norwood, MA 020062 USA) 1987.
4. Bridges, J.E Milleta J. and Ricketts.L.W., "EMP Radiation and Protective techniques", John Wiley and sons, USA 1976.
5. William Duff G., & Donald White R. J, "Series on Electromagnetic Interference and Compatibility", Vol.
6. Weston David A., "Electromagnetic Compatibility, Principles and Applications", 1991.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	1	1	2
CO2	3	2	2	3	2	2
CO3	3	2	2	2	1	3
CO4	3	2	2	2	2	2
CO5	3	2	2	3	2	3
Average	**3**	**2**	**2**	**2.2**	**1.6**	**2.4**

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