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.

Attested

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ANNA UNIVERSITY, CHENNAI
UNIVERSITY DEPARTMENTS
REGULATIONS -2023
CHOICE BASED CREDIT SYSTEM
M.E. HIGH VOLTAGE ENGINEERING
CURRICULUM AND SYLLABUS I TO IV SEMESTERS

1.PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

I.	To produce graduates with the domain knowledge in High Voltage engineering who are employable in public and private organisations
II.	To develop graduates to identify and provide solutions to industrial, societal needs related to high voltage applications
III.	To strengthen graduates to inculcate the entrepreneurial skills along with lifelong learning with professional ethics.

2.PROGRAMME OUTCOMES (POs)

On successful completion of the M.E. High Voltage Engineering programme, the graduates would have	
PO1	An ability to independently carry out the research/investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report/document.
PO3	An ability to demonstrate a degree of mastery in high voltage engineering towards the design and testing of high voltage system and equipment.
PO4	An ability to model and analyse power system and equipment using electromagnetic field computation softwares.
PO5	An ability to conduct experiments and research in the areas of generation and measurement of high voltages, material characterization and applications of high electric fields in interdisciplinary areas.
PO6	An ability to design insulation schemes for power system apparatus and to conduct dielectric tests as per national and international test standards with environmental consciousness and sustainable development.

3. MAPPING OF PEOs with POs

PROGRAMME EDUCATIONAL OBJECTIVES	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
I	3	1	2	2	3	3
II	3	2	3	3	2	3
III	3	2	3	2	3	3

Mapped with 1, 2, 3 & -, scale: 1-low ; 2-medium ; 3-high

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PROGRAM ARTICULATION MATRIX

			PO1	PO2	PO3	PO4	PO5	PO6
YEAR 1	SEM 1	Research Methodology and IPR	-	-	-	-	-	-
		High Voltage Generation and Measurements	3	1	2	1.8	3	2
		Electrical Transients in Power System	3	1.6	1.8	1.4	1	1.4
		Electromagnetic Field Computation and Modelling	2	1	2	3	-	2.4
		Insulation Technology	3	2.2	3	2.6	3	2.6
		Professional Elective I	-	-	-	-	-	-
		High Voltage Generation and Measurement Laboratory	3	2	3	-	3	3
		Electromagnetic Field Computation Laboratory	3	2	2	3	-	3
	SEM 2	High Voltage Testing Techniques	2.8	2.2	2.6	1.4	2.8	2.8
		Insulation Design of High Voltage Power Apparatus	2	2	3	3	-	3
		Principles of Electric Power Transmission	2.8	1.2	1.6	2.0	1.0	2.0
		Professional Elective II	-	-	-	-	-	-
		Professional Elective III	-	-	-	-	-	-
		Insulation Design Laboratory	3	2	3	3	-	3
		Advanced High Voltage Laboratory	3	2	3	-	3	3
YEAR 2	SEM 3	Professional Elective IV	-	-	-	-	-	-
		Professional Elective V	-	-	-	-	-	-
		Professional Elective VI	-	-	-	-	-	-
		Project Work I	3	2	3	2.4	1.8	1.8
	SEM 4	Project Phase II	3	1.8	3	2.2	2.4	2.6

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M.E. HIGH VOLTAGE ENGINEERING
CURRICULUM AND SYLLABUS I TO IV SEMESTERS

SEMESTER I

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	RM3151	Research Methodology and IPR	RMC	2	1	0	3	3
2.	HV3101	High Voltage Generation and Measurements	PCC	3	0	0	3	3
3.	HV3151	Electrical Transients in Power System	PCC	3	1	0	4	4
4.	HV3152	Electromagnetic Field Computation and Modelling	PCC	3	0	0	3	3
5.	HV3153	Insulation Technology	FC	3	0	0	3	3
6.		Professional Elective I	PEC	3	0	0	3	3
PRACTICALS								
7.	HV3111	High Voltage Generation and Measurements Laboratory	PCC	0	0	4	4	2
8.	HV3112	Electromagnetic Field Computation Laboratory	PCC	0	0	4	4	2
			TOTAL	**17**	**2**	**8**	**27**	**23**

SEMESTER II

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	HV3201	High Voltage Testing Techniques	PCC	4	0	0	4	4
2.	HV3202	Insulation Design of High Voltage Power Apparatus	PCC	3	0	0	3	3
3.	HV3203	Principles of Electric Power Transmission	PCC	3	0	0	3	3
4.		Professional Elective II	PEC	3	0	0	3	3
5.		Professional Elective III	PEC	3	0	0	3	3
PRACTICALS								
6.	HV3211	Insulation Design Laboratory	PCC	0	0	4	4	2
7.	HV3212	Advanced High Voltage Laboratory	PCC	0	0	4	4	2
			TOTAL	**16**	**0**	**8**	**24**	**20**

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SEMESTER III

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	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.	HV3311	Project Work I	EEC	0	0	12	12	6
			TOTAL	**9**	**0**	**12**	**21**	**15**

SEMESTER IV

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICALS								
1.	HV3411	Project Work II	EEC	0	0	24	24	12
			TOTAL	**0**	**0**	**24**	**24**	**12**

TOTAL NO. OF CREDITS: 70

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FOUNDATION COURSES (FC)

S.NO	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			L	T	P		
1.	HV3153	Insulation Technology	3	0	0	3	1

RESEARCH METHODOLOGY AND IPR COURSES (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.	HV3101	High Voltage Generation and Measurements	3	0	0	3	1
2.	HV3151	Electrical Transients in Power systems	3	1	0	4	1
3.	HV3152	Electromagnetic Field Computation and Modelling	3	0	0	3	1
4.	HV3111	High Voltage Generation and Measurement Laboratory	0	0	4	2	1
5.	HV3112	Electromagnetic Field Computation Laboratory	0	0	4	2	1
6.	HV3201	High Voltage Testing Techniques	4	0	0	4	2
7.	HV3202	Insulation Design of High Voltage Power Apparatus	3	0	0	3	2
8.	HV3203	Principles of Electric Power Transmission	3	0	0	3	2
9.	HV3211	Insulation Design Laboratory	0	0	4	2	2
10.	HV3212	Advanced High Voltage Laboratory	0	0	4	2	2
					TOTAL CREDITS	28	

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PROFESSIONAL ELECTIVES COURSES (PEC)
(HIGH VOLTAGE ENGINEERING)

S. NO.	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS
			L	T	P	
1.	HV3001	Design of High Voltage Switchgear	3	0	0	3
2.	HV3002	Condition Monitoring of High Voltage Power Equipment	3	0	0	3
3.	HV3003	Nano Dielectrics	3	0	0	3
4.	HV3004	Applications of High Electric Fields	3	0	0	3
5.	HV3051	Design of Substations	3	0	0	3
6.	HV3052	Electromagnetic Interference and Compatibility	3	0	0	3
7.	HV3005	Pollution Performance of Power Apparatus and Systems	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.	PS3151	Analysis and Computation of Electromagnetic Transients in Power Systems	3	0	0	3
2.	PS3152	HVDC and FACTS	3	0	0	3
3.	PS3051	Computational Intelligence Techniques to Power Systems	3	0	0	3
4.	PS3251	Restructured Power System	3	0	0	3
5.	PS3053	Optimization Techniques to Power System Engineering	3	0	0	3
6.	PS3052	Distributed Generation and Micro Grid	3	0	0	3
7.	PS3252	Smart Grid	3	0	0	3
8.	PS3054	Wind Energy Conversion Systems	3	0	0	3
9.	PW3151	Electric Vehicle Charging Infrastructure	3	0	0	3
10.	PW3252	Optimization Techniques for Energy Management	3	0	0	3
11.	PW3251	Energy Storage Systems	3	0	0	3
12.	PW3054	Grid Integration of Renewable Energy Sources	3	0	0	3
13.	PW3058	Waste to Energy Conversion	3	0	0	3
14.	PW3055	IOT for Smart Power Systems	3	0	0	3

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15.	PW3057	Renewable Energy Technology	3	0	0	3
16.	PW3053	Energy Efficient Buildings	3	0	0	3
17.	PW3056	Micro Grid Operation and Control	3	0	0	3
18.	PW3052	Electric Vehicles and Power Management	3	0	0	3
19.	PE3151	Analysis of Power Converters	3	0	0	3
20.	PE3052	Multilevel Converters	3	0	0	3
21.	PE3053	Power Quality	3	0	0	3
22.	PE3252	Special Electrical Machines	3	0	0	3
23.	PE3251	Analysis of Electrical Drives	3	0	0	3
24.	PE3054	Rectifiers and Resonant Converters	3	0	0	3
25.	CO3057	Optimal Control and Filtering	3	0	0	3
26.	CO3152	Intelligent Controllers	3	0	0	3
27.	CO3051	Biomedical Instrumentation	3	0	0	3
28.	CO3056	Multi Sensor Data Fusion	3	0	0	3
29.	CO3251	Modern Automation Systems	3	0	0	3
30.	ET3151	Design of Embedded Systems	3	0	0	3
31.	ET3054	Embedded Controllers for EV Applications	3	0	0	3
32.	ET3251	Automotive Embedded Systems	3	0	0	0
33.	ET3057	Information Modelling for Smart Process	3	0	0	3
34.	ET3062	MEMS and NEMS Technology	3	0	0	3
35.	ET3065	Robotics and Automation	3	0	0	3
36.	ET3063	Python Programming for Machine Learning	3	0	0	3
37.	ET3052	Blockchain Technologies	3	0	0	3
38.	ET3051	Big Data Analytics	3	0	0	3
39.	ET3055	Embedded Networking and Automation of Electrical System	3	0	0	3
40.	ET3066	Smart System Design	3	0	0	3
41.	ET3064	Reconfigurable Processor and SoC Design	3	0	0	3
42.	ET3056	Entrepreneurship and Embedded Product Development	3	0	0	3
43.	ET3061	Machine Learning and Deep Learning	3	0	0	3
44.	MA3161	Statistical Methods for Engineers	4	0	0	4
45.	MA3155	Advanced Numerical Methods	4	0	0	4
46.	MA3156	Applied Mathematics for Electrical Engineers	4	0	0	4 Attested
47.	MA3160	Probability and Statistical Methods	4	0	0	4

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EMPLOYABILITY ENHANCEMENT COURSES (EEC)

S. No.	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			L	T	P		
1.	HV3311	Project Work I	0	0	12	6	3
2.	HV3411	Project Work II	0	0	24	12	4
					TOTAL CREDITS	18	

SUMMARY

SL. NO.	SUBJECT AREA	CREDITS PER SEMESTER				TOTAL CREDITS
		I	II	III	IV	
1.	**FC**	3	0	0	0	3
2.	**RMC**	3	0	0	0	3
3.	**PCC**	14	14	0	0	28
4.	**PEC**	3	6	9	0	18
5.	**EEC**	0	0	6	12	18
	TOTAL CREDITS	**23**	**20**	**15**	**12**	**70**

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RM3151 RESEARCH METHODOLOGY AND IPR **L T 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.

HV3101 HIGH VOLTAGE GENERATION AND MEASUREMENTS **L T P C**
3 0 0 3

UNIT I GENERATION OF DIRECT VOLTAGES 9
Requirements of HV generation in Laboratory, voltage stress, testing voltages, generation of direct voltages – AC to DC conversion – single phase rectifier circuits – cascade circuits – voltage multiplier circuits – Cockcroft-Walton circuit – voltage regulation – ripple factor – Electrostatic generators.

UNIT II GENERATION OF ALTERNATING VOLTAGES 9
Testing transformer – single unit testing transformer, cascaded transformer – equivalent circuit of cascaded transformer –resonant circuits – resonant transformer – voltage regulation.

UNIT III GENERATION OF IMPULSE VOLTAGES 9
Impulse voltage, general shape and definition of lightning impulses, generator circuit – Marx generator –analysis of various impulse voltage generator circuits, controlled switching – multistage impulse generator circuits, Solid state Marx generator – Switching impulse generator circuits – generation of non-standard impulse voltages and very fast transient voltage (VFTO)- Relevant IS and IEC Standards.

UNIT IV MEASURMENT OF HIGH VOLTAGES 9
Measurement of high AC, DC Impulse voltages - Peak voltage measurements by sphere gaps – Electrostatic voltmeter – generating voltmeters and field sensors – Chubb-Fortescue method – voltage dividers, types, dynamic response - Fast digital transient recorders for impulse measurements- Relevant IS and IEC Standards.

UNIT V GENERATION AND MEASUREMENT OF IMPULSE CURRENTS 9
Generation of impulse currents, conversion of impulse voltage generator to impulse current generator- measurement of high DC, AC and impulse currents – current shunts, measurement using magnetic potentiometers, magnetic coupling, Hall Generators, magneto-optical method and current transformers

TOTAL = 45 PERIODS

COURSE OUTCOMES:
CO1: Ability to design, simulate and generate HVDC
CO2: Ability to design, simulate and generate HVAC
CO3: Ability to design, simulate and generate impulse voltage
CO4: Ability to design and analyze the suitable measuring circuits for HV
CO5: Ability to design the suitable generating and measuring circuits for impulse current

REFERENCES

1. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsvier India Pvt. Ltd, Second edition, 2008
2. Dieter Kind, Kurt Feser, “High Voltage Test Techniques”, SBA Electrical Engineering Series, New Delhi, Second edition, 2001.
3. Naidu M S and Kamaraju V, “High Voltage Engineering”, Tata McGraw-hill Publishing Company Ltd., Sixth edition., New Delhi, 2020.
4. Gallagher, T.J., and Permain, A., “High Voltage Measurement, Testing and Design”, John Wiley Sons, New York, First edition 1984.
5. R.Mazen Abdel-Salam, Hussein Anis, Ahdab El-Morshedy, RoshdyRadwan, “High Voltage Engineering Theory and Practice” Second Edition, Revised and Expanded, Marcel Dekker, Inc., New York, 2000.

6. N.H.Malik, A.A.Al_Arainy, M.I.Qureshi, “Electrical Insulation in Power Systems”, marcel Dekker,Inc., New York 1988.
7. Adolf J. Schwab, “High Voltage Measurement Techniques”, M.I.T Press, 1972.

MAPPING OF COs WITH POs

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

HV3151 ELECTRICAL TRANSIENTS IN POWER SYSTEM **LT P C**
3 1 0 4

UNIT I LIGHTNING OVERVOLTAGES 9+3

Classification of overvoltages - Mechanism, parameters and characteristics of lightning strokes, protective shadow, striking distance, mathematical model for lightning, Grounding for protection against lightning — Steady state and dynamic tower-footing resistance, substation grounding Grid, Direct lightning strokes to overhead lines, without and with shield wires.

UNIT II SWITCHING AND TEMPORARY OVERVOLTAGES 9+3

Origin and characteristics of switching transients – double frequency transients – system performance under switching surges- Ferranti Effect, Temporary overvoltages – load rejection – line faults – ferroresonance, VFTO – Control of switching transients.

UNIT III TRAVELLING WAVES ON TRANSMISSION LINE 9+3

Circuits and distributed constants, wave equation, reflection and refraction at various transition points– behavior of travelling waves at the line terminations – Lattice Diagrams – attenuation and distortion, lossless and distortion less lines – multi conductor system.

UNIT IV INSULATION CO-ORDINATION 9+3

Insulation co-ordination, Insulation strength and their selection- Evaluation of insulation strength standard BILs-Characteristics of protective devices, applications, location of arresters — insulation co-ordination in AIS and GIS.

UNIT V COMPUTATION OF POWER SYSTEM TRANSIENTS 9+3

Computation of transients using EMTP -Modelling of power system components- Simple case studies – Analysis of reflection and refraction waves at transition points and line terminations.

L=45: T=15, TOTAL = 60 PERIODS

COURSEOUTCOMES:

CO1: Ability to understand generation of lightning overvoltages and importance of grounding
CO2: Ability to know about generation and control of switching and temporary overvoltages
CO3: Ability to predict overvoltages in power system using travelling wave theory
CO4: Ability to coordinate the insulation level of the power system
CO5: Ability to compute overvoltages using EMTP

REFERENCES

1. Pritindra Chowdhari, "Electromagnetic transients in Power System", John Wiley and Sons Inc.,Second Edition, 2008.
2. Allan Greenwood, "Electrical Transients in Power System", Wiley & Sons Inc. New York,2012.
3. Andrew R. Hileman, "Insulation Coordination for Power Systems", CRC press, Taylor &Francis Group, New York, 1999.
4. Klaus Ragaller, "Surges in High Voltage Networks", Plenum Press, New York, 1980.
5. Rakosh Das Begamudre, "Extra High Voltage AC Transmission Engineering", (Second edition) Newage International (P) Ltd., New Delhi, 2014.
6. Naidu M S and Kamaraju V, "High Voltage Engineering", Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2020.

7. IEEE Guide for safety in AC substation grounding IEEE Standard 80-2000.
8. Working Group 33/13-09 (1988), 'Very fast transient phenomena associated with Gas Insulated System', CIGRE, 33-13, pp. 1-20.
9. R. Ramanujam, "Computational Electromagnetic Transients: Modeling, Solution Methods andSimulation", I.K. International Publishing House Pvt. Ltd, New Delhi -110 016, 2019
10. Working Group WG 01 Guide to procedures for estimating the lightning performance of transmission lines, CIGRE 01-33, pp. 26-35.
11. Insulation Coordination Part 1 - Definition, Principles and Rules, IEC 60071 - 1, Edition 9.0, 2019-08
12. Hao Zhou et al, "Ultra-high Voltage AC/DC Power Transmission", Springer, 2018
13. Working Group C4.307, "Resonance and Ferro resonance in Power Networks", CIGRE 569, 88 – 97.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	1	1	1
CO2	3	2	2	1	1	1
CO3	3	2	2	1	1	1
CO4	3	1	2	1	1	3
CO5	3	1	1	3	1	1
Average	**3**	**1.6**	**1.8**	**1.4**	**1**	**1.4**

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**

HV3153 **INSULATION TECHNOLOGY** **LT P C**
3 0 0 3

UNIT I PROPERTIES OF DIELECTRICS IN STATIC FIELDS **9**

Static dielectric constant – Polarization and dielectric constant – atomic interpretation of the dielectric constant of mono-atomic gases –dependence of permittivity on various factors– internal field in solids and liquids.

UNIT II BEHAVIOR OF DIELECTRICS IN ALTERNATING FIELDS **9**

Frequency dependence of the electronic polarizability – ionic polarization as a function of frequency – complex dielectric constant of non-dipolar solids – dipolar relaxation – dielectric losses.

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UNIT III BREAKDOWN MECHANISMS IN GASEOUS DIELECTRICS **9**

Behavior of gaseous dielectrics in electric fields – gaseous discharges – different ionization

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processes – effect of electrodes on gaseous discharge – Townsend's theory, Streamer theory – electronegative gases, gaseous discharges in non-uniform fields – alternate Green gases and mixture of gases- breakdown in vacuum insulation.

UNIT IV BREAKDOWN MECHANISMS IN SOLID AND LIQUID DIELECTRICS 9

Solid Dielectrics-Intrinsic breakdown of solid dielectrics – electromechanical breakdown-Streamer breakdown, thermal breakdown - electrochemical breakdown – tracking and treeing – thermal and electrical ageing and partial discharges - classification of solid dielectrics, composite insulation. Liquids dielectrics- conduction and breakdown in pure, commercial liquids and Biodegradable oils.

UNIT V APPLICATION OF INSULATING MATERIALS 9

Application of insulating materials in power equipment and recent advancements-environment friendly and recyclable insulation.

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1 Ability to understand the fundamental behavior of dielectrics in static fields.
CO2 Ability to understand the fundamental behavior of dielectrics in alternating fields.
CO3 To understand the performance of gaseous dielectrics.
CO4 Ability to understand the behavior of liquid and solid dielectrics
CO5 Ability to select the suitable insulation for an electrical power equipment

REFERENCES

1. Thermal Insulation and Radiation Control Technologies for Buildings - Jankosny, David W. Yarbrough - Springer - 2022.
2. M.S Naidu, V.Kamaraj, “High Voltage Engineering”, Tata Mc Graw-Hill Publishing Company Ltd., New Delhi, 6th Edition 2020.
3. Alston, L.L, “High Voltage Technology”, Oxford University Press, London, 1968 (B.S Publications, Second Indian Edition 2008).
4. Introduction to Polarization Physics – Sandibek B. Nurushev, Mikhail F. Runtso, Mikhail N. Strikhanov - Sripnger - 2013
5. Adrinaus, J.Dekker, “Electrical Engineering Materials”, Prentice Hall of India Pvt. Ltd., New Delhi, 1959.
6. Dieter Kind and Hermann Karner, “High Voltage Insulation Technology”, 1985. (Translated from German by Y. Narayana Rao, Friedr. Vieweg & Sohn, Braunschweig).
7. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsvier India Pvt. Ltd, 2005
8. V.Y.Ushakov, “Insulation of High Voltage Equipment”, Springer ISBN.3-540-20729-5, 2004.
9. R.E.james and Q.Su,“Condition Assessment of High Voltage Insulation in Power System Equipment”, IET publications,London,U.K,2008

MAPPING OF COs WITH POs

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

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HV3111 **HIGH VOLTAGE GENERATION AND MEASUREMENTS LABORATORY** **L T P C 0 0 4 2**

LIST OF EXPERIMENTS

1. Design and Analysis of high voltage generators using circuit simulation package

1. Design and Analysis of high voltage DC generators – half wave rectifier, full wave rectifier, voltage doubler, voltage multiplier (Cockroft - Walton Circuit)- calculation of ripple factor, efficiency and regulation for various generator circuit parameters and loads- Sensitivity analyses
2. Design and Analysis of lightning Impulse voltage generators – Marx circuit- measurement of lightning impulse voltage wave shape parameters for different generator circuit parameters and test objects
3. Design and Analysis of Switching and non-standard impulses, Very fast transient overvoltages
4. Design and Analysis of pulse generators

2. Generation and measurement of high voltages

1. Generation, calibration and measurement of HVDC –measurement of ripple and peak voltage for different charging capacitors
2. Generation, calibration and measurement of HVAC
3. Generation, calibration and measurement of standard lightning impulse voltages
4. Generation, calibration and measurement of Switching impulse voltages
5. Generation and measurement of VFTO

TOTAL = 60 PERIODS

COURSE OUTCOMES:

Upon the successful completion of the course, students will be able to:
CO1: Design and analyse high voltage generators using circuit simulation package
CO2: Generate high voltages in the laboratory
CO3: Calibrate and measure high voltages in the laboratory

REFERENCES:

1. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsevier India Pvt. Ltd, Second edition, 2008
2. Dieter Kind, Kurt Feser, “High Voltage Test Techniques”, SBA Electrical Engineering Series, New Delhi, 1999.
3. Naidu M S and Kamaraju V, “High Voltage Engineering”, Tata McGraw-hill Publishing Company Ltd., Fifth edition., New Delhi, 2017

MAPPING OF COs WITH POs

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

Attested

HV3112 ELECTROMAGNETIC FIELD COMPUTATION LABORATORY **LT P C**
0 0 4 2

LIST OF EXPERIMENTS

1. Computation and Graphical representation of Gradient, Divergence and Curl fields (using Mathematical Development Tool)
2. Electrostatics: Computation of Voltage distribution, Electric field intensity and Capacitance for simple configurations -Parallel plate capacitor and Coaxial cable
3. Magnetostatics: Computation of magnetic field intensity and Inductance for simple configurations - Circular ring , Solenoid and magnetic circuit with air gap, Force on Conductors
4. AC conduction analysis: Transmission line - single phase and three phase configurations
5. Eddy current analysis : calculation of R(f) and depth of penetration
6. Field computation and analysis on
   i. Cylindrical magnetic actuator- force calculation and design optimization
   ii. Single phase transformer- realization of Equivalent circuit using OC and SC tests
   iii. High Voltage Insulator - Electric field analysis
   iv. Rotating machine - magnetic field analysis

TOTAL = 60 PERIODS

COURSE OUTCOMES:

Upon the successful completion of the course, students will be able to:
CO1 Compute, represent and interpret electromagnetic field distribution
CO2 Formulate, solve and analyze EM problems for practical applications using FEM method
CO3 Evaluate and optimize the design of electrical equipment

REFERENCES

1. Matthew. N.O. Sadiku" Numerical techniques in electromagnetics", Second Edition, CRC Press,2000.
2. Nicola Bianchi, "Electrical Machine analysis using Finite Elements", Taylor and Francis Group, CRC Publishers, 2005.
3. Kuffel, E., Zaengl, W.S. and Kuffel J., "High Voltage Engineering Fundamentals", Elsevier India Pvt. Ltd, Second edition.,2008.

MAPPING OF COs WITH POs

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

HV3201 HIGH VOLTAGE TESTING TECHNIQUES LT P C
4 0 0 4

UNIT I INTRODUCTION 12

Objectives of high voltage testing, classification of testing methods- self restoration and non-self-restoration systems- IS/IEC/IEEE standards and specifications, measurement techniques - standard test cells, Diagnostic testing – online measurement,

UNIT II STATISTICAL EVALUTION OF MEASURED RESULTS 12

Determination of probability values, Distribution function of a measured quantity, confidence limits. Laboratory test procedures- - Multi-level method -'Up and Down' method - Extended Up and Down' method for determining the 50% disruptive discharge voltage, multi stress ageing, life data analysis

UNIT III TESTING TECHNIQUES FOR ELECTRICAL EQUIPMENT 12

Testing of insulators, bushings, air break switches, isolators, circuit breakers, power transformers, voltage transformers, current transformers, surge arresters, cable -testing methodology-recording of oscillograms - interpretation of test results

UNIT IV NON-DESTRUCTIVE INSULATION TEST TECHNIQUES 12

Dynamic properties of dielectrics-dielectric loss and capacitance measurement-partial discharge measurements-basic partial discharge (PD) circuit – PD currents- PD quantities -Digital PD instruments and measurements, acoustic, emission technique and UHF Techniques for PD identification, Corona and RIV measurements on line hardware

UNIT V POLLUTION TESTS AND DESIGN OF HIGH VOLTAGE LAB 12

Artificial Pollution tests- salt-fog method, solid layer method, Design of High voltage laboratory, equipment- fencing, earthing and shielding.

TOTAL = 60 PERIODS

COURSEOUTCOMES:

CO1: Ability to select appropriate type of test for each high voltage power apparatus
CO2: Ability to do life data analysis and statistical evaluation of measured results
CO3: Ability to conduct Dielectric tests as per standards on various HV power apparatus
CO4: Ability to carry out Non-destructive tests on evaluation of insulation characteristics
CO5: Ability to execute artificial pollution test and design different types of HV lab

REFERENCES

1. Dieter Kind, Kurt Feser, "High voltage test techniques", SBA Electrical Engineering Series, New Delhi, Second Edition 2001.
2. Naidu M.S. and Kamaraju V., "High voltage Engineering", Tata McGraw Hill Publishing Company Ltd., Sixth Edition., New Delhi, 2020.
3. Relevant test standards.
4. Kuffel, E., Zaengl, W.S. and Kuffel J., "High Voltage Engineering Fundamentals", Elsvier India P Ltd, Second edition., 2008
5. Gallagher, T.J., and Pearmain A., "High Voltage Measurements, Testing and Design", John Willey & Sons, New York, First Edition 1984.
6. IS, IEC and IEEE standards for "Dielectric Testing of High Voltage Apparatus" W.Nelson, Applied Life Data Analysis, John Wiley and Sons, New York, 1982.

7. W.Kennedy, “Recommended Dielectric Tests and Test Procedures for Converter Transformer and Smoothing Reactors”, IEEE Transactions on Power Delivery, Vol.1, No.3, pp 161-166, 1986.
8. IEC – 60270, “HV Test technique – Partial Discharge Mechanism”, 3rd Edition December 2000.
9. M.D Judd, Liyang, Ian BB Hunter, “P.D Monitoring of Power Transformers using UHF Sensors” Vol.21, No.2, pp5-14, 2004.
10. M.D Judd, Liyang, Ian BB Hunter “P.D Monitoring of Power Transformers using UHF Sensors Part II, Vol.21, No.3, pp 5-13, 2004.
11. Wolfgang Hauschild” High Voltage test and Measuring Techniques” Springer First Edition 2014

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	-	2	3
CO2	3	2	2	1	3	2
CO3	3	3	3	2	3	3
CO4	3	2	3	2	3	3
CO5	3	3	3	2	3	3
Average	**2.8**	**2.2**	**2.6**	**1.75**	**2.8**	**2.8**

HV3202 INSULATION DESIGN OF HIGH VOLTAGE POWER APPARATUS **LT P C 3 0 0 3**

UNIT I INTRODUCTION 9

Electrical field distribution and breakdown strength of insulating materials , factors affecting the breakdown strength , Uniform and non - uniform electric fields, Field utilization factor, electric field distribution in homogenous isotropic materials - symmetrical and asymmetrical electrode configurations - Coaxial cylindrical and spherical fields, Fields in multi dielectric materials-Parallel plate capacitors- coaxial cable – dielectric refraction : Transverse, longitudinal and inclined boundary conditions, floating electrodes, electrical field control techniques

UNIT II HV INSULATORS AND BUSHINGS 9

Insulators: Types and materials- Ceramic and non ceramic (polymeric) insulators - physical configurations, applications, merits and limitations, pollution flashover- mechanism of pollution flashover -pollution levels - leakage distances - mitigation of pollution flashover, Choice of insulator profile as per relevant standards.

Bushings: Non condenser and condenser Bushings – design methodology, Electric field control methods, Bushing applications.

UNIT III POWER TRANSFORMERS 9

Insulation schemes in transformer, types of transformer windings - layer, continuous disc and interleaved winding, calculation of winding capacitance and inductance, surge phenomena in

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transformer windings- Initial, intermediate and final voltage distribution-stress control techniques, Insulating materials, transformer insulation -design of internal, main and end insulation.

UNIT IV INSTRUMENT TRANSFORMERS AND CABLES 9

Instrument transformers: Classification based on insulating materials and design of potential and current transformers

Cables: Materials, Types of cables, cable constants, electrical stress, losses and ampacity, DC and sub sea cables, partial discharge in cables- treeing - ageing - life estimation, cable joints - capacitive grading- non-linear resistive grading

UNIT V SURGE ARRESTER 9

Evolution of overvoltage protection practice, Types of surge arresters - gapped and gapless, v-i characteristics of SiC and ZnO, Metal oxide arrester design based on housing materials and mechanical supporting structure , modeling of arrestor, voltage distribution along the arrester , effect of pollution , Insulation coordination

TOTAL = 45 PERIODS

COURSE OUTCOMES:

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

CO1 identify and analyze the factors influencing the performance of insulation of power equipment.
CO2 design high voltage Insulators and bushing
CO3 design and optimize the insulation design of the power transformer
CO4 apply the insulation design concept to Instrument transformers and cable
CO5 analyse the surge arresters design concepts based on construction , non-linear characteristics and housing

REFERENCES

1. Dieter Kind and Hermann Karner, “High Voltage insulation technology”, Translated from German by Y.Narayana Rao, Friedr. Vieweg&Sohn, Braunschweig, 1985.
2. Alston, L.L, “High Voltage Technology”, Oxford University Press, London 2011.
3. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsevier India Pvt. Ltd, Second edition.,2008.
4. Karsai, K.Kerenyi, D. and Kiss. L., “Large Power Transformers”, Elsevier, Armsterdam, 1987.
5. Feinberg, R., “Modern Power Transformer Practice”, The Macmillan Press Ltd., New York, 2013.
6. Looms, J.S.T., “Insulators for High Voltages”, IET, London, U.K, 1988.
7. S.V.Kulkarni, S.A.Khaparde, “Transformer Engineering Design and Practice”, Second edition, CRC press, New York, 2017.
8. Farouk A.M. Rizk, Giao. N.Trinh” High Voltage Engineering”, CRC Press (Taylor & Francis) 2014 Edition
9. Hugh M. Ryan, “High Voltage Engineering and testing”, The Institution of Engineering and Technology, London, UK, third Edition, 2013
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11. IEC 60815 Part 1,2 and 3 (2014), “Selection and dimensioning of polluted Insulators”.
12. IEC 60099 part 4 (2001) “Metal Oxide surge arrestors without gaps for A.C. systems”.

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13. A. Haddad and D. Warne, “Advances in high voltage engineering”, The Institution of Engineering and Technology, London, UK, 2004.
14. CIGRE WG A3.17, “MO surge arresters Stresses and test Procedures”, August 2013.
15. IEC 60099 part 5 (2001) “Surge arresters – Part 5: Selection and application recommendations”, Edition 3.0, 2018-01
16. Working Group A2/C4.39, “Electrical Transient Interaction Between Transformers and the Power System Part 1- Expertise”, CIGRE 577A, PP. 33 -80.

MAPPING OF COs WITH POs

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

HV3203 PRINCIPLES OF ELECTRIC POWER TRANSMISSION LT P C
3 0 0 3

UNIT I INTRODUCTION TO EHVAC TRANSMISSION 9
Standard transmission voltages-AC and DC – different line configurations– average values of line parameters – power handling capacity and line loss – costs of transmission lines and equipment – mechanical considerations in line performance.

UNIT II CALCULATION OF LINE PARAMETERS 9
Calculation of resistance, inductance and capacitance for multi-conductor lines – calculation of sequence inductances and capacitances – line parameters for different modes of propagation – effect of ground return.

UNIT III VOLTAGE GRADIENTS OF CONDUCTORS 9
Charge-potential relations for multi-conductor lines – surface voltage gradient on conductors – Mangoldt formula-gradient factors and their use - voltage gradients on conductors in the presence of ground wires on towers.

UNIT IV CORONA EFFECTS 9
I^2R loss and corona loss, corona current, charge – voltage diagram, effect of corona on travelling waves, Audible noise: generation, characteristics and limits-Radio interference : generation of corona pulses and properties, limits for RI, measurement of RI, RIV and excitation function –Television interference.

UNIT V ELECTROSTATIC FIELD AND DESIGN OF EHV LINES 9
Effect of EHV line on heavy vehicles - calculation of electrostatic field of AC lines- effect of high field on humans, animals, and plants - measurement of electrostatic fields - electrostatic Induction in unenergised circuit of a D/C line - induced voltages in insulated ground wires – electromagnetic interference, HVDC line: design-tower-ROW-insulators.

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1: Ability to know voltage level and line configurations
CO2: Ability to compute line parameters with ground return
CO3: Ability to know the effects of voltage gradients of transmission line conductors
CO4: Ability to familiarize the merits and demerits of corona effects
CO5: Ability to understand effects of electrostatic field on living and nonliving organisms

REFERENCES

1. Rakosh Das Begamudre, “Extra High Voltage AC Transmission Engineering”, Second Edition,New Age International Pvt. Ltd., 2014.
2. Pritindra Chowdhari, “Electromagnetic transients in Power System”, John Wiley and Sons Inc.,2009.
3. Andrew R. Hileman, “Insulation Coordination for Power Systems”, CRC press, Taylor &Francis Group, New York, 1999.
4. Power Engineer’s Handbook, Revised and Enlarged 6th Edition, TNEB Engineers’
5. Association, October 2002.
6. Sunil S.Rao, “EHV-AC, HVDC Transmission & Distribution Engineering”, Third Edition,Khanna Publishers, 2008
7. Gas Insulated Transmission Lines (GIL) - by Hermann Koch, Oct 2011, John Wiley & Sons.
8. William H. Bailey, Deborah E. Weil and James R. Stewart . “A Review on ,”HVDC Power Transmission Environmental Issues”, Oak Ridge National Laboratory.
9. J.C Molburg, J.A. Kavicky, and K.C. Picel ,”A report on The design, Construction and operation of Long-distance High-Voltage Electricity Transmission Technologies” , Argonne (National Laboratory)
10. P.Kundur,“Power system stability and control”,McGraw-Hill,Inc.,2006
11. K.R.Padiyar, “HVDC Power Transmission Systems”, New Age International (P) Ltd.,New Delhi,2017.
12. EPRI, Transmission Line Reference Book - 345 kV and above, Second Edition 1982
13. EPRI, AC Transmission Line Reference Book-200 kV and above, Edition 2016
14. Working Group B2.03, “Use of corona rings to control the electrical field along transmission line composite insulators”, CIGRE 284.
15. Working Group 36.01, “Interferences produced by corona effect of electric Systems”, CIGRE 020.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	1	1	2
CO2	3	1	2	1	1	2
CO3	3	2	2	3	1	2
CO4	2	1	1	2	1	2
CO5	3	1	1	3	1	2
Average	**2.8**	**1.2**	**1.6**	**2.0**	**1.0**	**2.0**

HV3211 INSULATION DESIGN LABORATORY L T P C
0 0 4 2

LIST OF EXPERIMENTS

Electric field analysis and the transient response of the equipment are to be carried out using Electromagnetic Field computational software (FEM based) and Circuit simulation package respectively.

1. Electric field in homogeneous and non-homogeneous materials
   i. Symmetrical and asymmetrical electrode configurations
   ii. Parallel plate, coaxial cable and concentric spheres
2. Dielectric refraction of electric fields in practical insulation systems – Transverse, longitudinal and inclined boundary condition: electric field behaviour for a finite contact angle.
3. Design of insulator with grading and corona rings
4. Design of condenser and non-condenser bushings
5. Design of cable joints (capacitive grading)
6. Transformer design
   i. Stress control techniques for different types of winding in transformer (layer and disc)
   ii. High frequency equivalent circuit – extraction of L and C parameters
   iii. Transient analysis
7. Insulation design of Surge Arrester with grading rings

TOTAL : 60 PERIODS

COURSEOUTCOMES:
Upon the successful completion of the course, students will be able to:
CO1 compute and analyse the electric field distribution and utilization for basic configurations
CO2 design and assess high voltage insulators , bushing , cable joint , transformer winding and surge arresters
CO3 identify and apply suitable electric stress control techniques for HV equipment

REFERENCES :

1. Dieter Kind and Hermann Karner, “High Voltage insulation technology”, Translated from German by Y.Narayana Rao, Friedr. Vieweg&Sohn, Braunschweig, 1985.
2. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsvier India Pvt. Ltd, Second edition.,2008.
3. Karsai, K.Kerenyi, D. and Kiss. L., “Large Power Transformers”, Elsevier, Armsterdam, 1987.

MAPPING OF COs WITH POs

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

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HV3212 ADVANCED HIGH VOLTAGE LABORATORY **LT P C**
0 0 4 2

LIST OF EXPERIMENTS

1. Study on AC, DC and LI breakdown voltage of air under uniform and non- uniform electrode configurations
2. Study on Impulse voltage breakdown characteristics of air under different pressures.
3. Study on AC and DC breakdown voltage of solid and liquid dielectrics as per standards.
4. Measurement of Electric and Magnetic fields using field meters
5. Measurement of resonant frequencies and internal voltage distribution in transformer windings
6. Measurement of Partial Discharges
7. Measurement of Harmonics using energy analyzer
8. Dielectric withstand tests on Insulator / Bushing
9. Dielectric withstand tests on Air Break Switch / Circuit Breaker
10. Dielectric withstand tests on Transformer
11. Enhanced extraction of Bio compounds by Pulsed Electric Field
12. Shelf Life study of Liquid Foods by Pulsed Electric Field.
13. Intercellular Impedance measurements.

TOTAL = 60 PERIODS

COURSE OUTCOMES:

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

CO1 analyze the breakdown characteristics of different types of dielectric media under different voltages , pressures and electrode configurations
CO2 check the E/H field exposure levels
CO3 analyze the transient behavior of transformer windings under various types of over voltages
CO4 test the power equipment as per standards for Certification purpose
CO5 apply pulsed electric fields for interdisciplinary applications

REFERENCES:

1. Dieter Kind, Kurt Feser, “High voltage test techniques”, SBA Electrical Engineering Series, New Delhi, 1999.
2. Naidu M.S. and Kamaraju V., “High voltage Engineering”, Tata McGraw Hill Publishing Company Ltd., Fifth Edition., New Delhi, 2017.
3. Relevant National and international test standards
4. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsevier India P Ltd, Second edition., 2008
5. Respective IS/ IEC /IEEE standards for Dielectric Testing of specific HV equipment

MAPPING OF COs WITH POs

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

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HV3311 **PROJECT WORK I** **L T P C**
0 0 12 6

Broad Area of Research Include:

- Design of High Voltage Transformers, Insulators, Bushings Circuit breakers , Cables surge Arrestors etc.,
- Electric Vehicle Charging station protection.
- Design and characterisation of different Dielectric and Insulation systems
- Nano Dielectrics,
- Pulsed Electric Fields Applications in Food , Cancer Treatment , Extraction of Bio-active components , Agriculture and water treatments,
- E&H Field Distribution studies -Simulation Software (FEM, ANSYS, COMSOL, EMTP)

Course Outcome:

CO1: Ability to apply reasoning informed by contextual knowledge to access societal, heath, safety, legal and cultural issues and the consequent responsibilities relevant to engineering practice
CO2: Ability to do intensive literature review on the chosen project
CO3: Ability to formulate, model and solve electromagnetic problems
CO4: Ability to document and present a sustainable technical report
CO5: Ability to communicate effectively on complex engineering activities with engineering community and the society at large.

TOTAL : 180 PERIODS

MAPPING OF COs WITH POs

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

HV3411 **PROJECT WORK II** **L T P C**
0 0 24 12

Broad Area of Research Include:

- Design of High Voltage Transformers, Insulators, Bushings Circuit breakers, Cables surge Arrestors etc.,
- Electric Vehicle Charging station protection.
- Design and characterisation of different Dielectric and Insulation systems
- Nano Dielectrics,
- Pulsed Electric Fields Applications in Food, Cancer Treatment , Extraction of Bio-active components , Agriculture and water treatments,
- E&H Field Distribution studies -Simulation Software (FEM, ANSYS, COMSOL, EMTP)

Course Outcome:

CO1: Ability to apply the knowledge of mathematics, science, engineering fundamentals and high voltage engineering to the solution of complex engineering problems.

CO2: Ability to conduct experiments effectively as an individual and as a member or leader in diverse teams, and in multidisciplinary areas and commit to professional ethics.

CO3: Ability to design experiments, analysis and interpretation of data and synthesis of information to provide valid conclusions.

CO4: Ability to create, select and apply appropriate techniques, resources and modern engineering solutions to complex engineering activities with an understanding of limitations.

CO5: Ability to recognize, prepare and engage in independent and lifelong learning.

TOTAL : 360 PERIODS

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	2	3
CO2	3	1	3	2	3	3
CO3	3	3	3	3	3	3
CO4	3	2	3	2	2	2
CO5	3	2	3	2	2	2
Average	**3**	**1.8**	**3**	**2.2**	**2.4**	**2.6**

PROFESSIONAL ELECTIVE COURSES (PEC)

HV3001 DESIGN OF HIGH VOLTAGE SWITCHGEAR **L T P C**
3 0 0 3

UNIT I INTRODUCTION 9

Insulation of switchgear - coordination between inner and external insulation, Insulation clearances in air, oil, SF6 and vacuum, bushing insulation, solid insulating materials – dielectric and mechanical strength consideration – Isolating, earthing and load switches.

UNIT II CIRCUIT INTERRUPTION 9

Switchgear terminology – Arc characteristics – direct and alternating current interruption – arc quenching phenomena – computer simulation of arc models – transient re-striking voltage – RRRV-recovery voltage-current chopping-capacitive current breaking-auto re-closing.

UNIT III DESIGN OF AIR CIRCUIT BREAKERS 9

General Layout – Electric Arc Behavior in a Longitudinal Flow of Compressed Air – Thermodynamic Clogging of the Blast Nozzle, Nozzle Section Vs Breaking Current Relation – Recovery of Dielectric Strength in Axial Blast Interrupters – Aiding Arc Extinction with Shunt Resistors and Capacitors – Gas Dynamics of Air Circuit Breakers – Analysis and Selection of Interrupting Chamber Parameters – Control System Components – Air Circuit Breaker Design – Case studies

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UNIT IV DESIGN OF OIL CIRCUIT BREAKERS 9

Layout of Bulk and Low-Oil Breakers – Construction and Operation of Interrupters – Extinction Chamber Pressure Analysis – Auto-Reclosing Duty and Frequent Make-Break Operations – Operating Mechanisms – Driving and Tripping Mechanisms – Trends in the Development of Oil Less Circuit Breakers – Breaker Design – Case studies

UNIT V DESIGN OF SF_6 AND VACUUM CIRCUIT BREAKERS 9

Insulating and Interrupting Properties of SF6 –Analysis and Construction of SF6 Circuit Breakers – Vacuum circuit breakers: Status and trends in continuous current and interrupting ratings – Mechanical and thermal withstand capabilities– Construction and layout – Breaker design – Case studies

TOTAL = 45 PERIODS

COURSEOUTCOMES:

CO1: Ability to analyze insulation clearances in external and internal installations
CO2: Ability to analyze and model arc interruption in circuit breakers
CO3: Ability to design different air circuit breakers effectively
CO4: Ability to meet design trends in oil-less circuit breakers
CO5: Ability to design and analyze SF6 and VCB circuit breakers

REFERENCES

1. Chunikhin, A. and Zhavoronkov, M., “High Voltage Switchgear Analysis and Design”, Mir Publishers, Moscow, 1989.
2. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsvier India Pvt. Ltd, 2008
3. Flursscheim, C.H. (Editor), “Power Circuit Breaker-Theory and Design”, IEE Monograph Series 17, Peter Peregrinus Ltd., Southgate House, Stevenage, Herts, SC1 1HQ, England, 1977.
4. Ananthakrishnan S and Guruprasad K.P., “Transient Recovery Voltage and Circuit Breakers”, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 1999.
5. Funio Nakanishi, “Switching Phenomena in High Voltage Circuit Breakers”, Marcel Dekker Inc., New York, 1991.
6. IEC 62271-100 (Ed 1.1), “High-voltage switchgear and control gear – Part 100: High-voltage alternating-current circuit-breakers” Annex E
7. Working Group 13.CC.03, “Transient recovery voltages in medium voltage networks”, CIGRE 134.
8. CIGRE Green Book, & “Switching Equipment”, Study Committee A3: High Voltage Equipment, PP 83 -155.

MAPPING OF COs WITH POs

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

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HV3002 CONDITION MONITORING OF HIGH VOLTAGE POWER EQUIPMENT **LT P C 3 0 0 3**

UNIT I BASICS OF CONDITION MONITORING 9

Need for Condition monitoring, Diagnostic methods- Requirements of diagnosis methods, design acceptance test , age related failure , insulation assessment methodologies, Destructive and non-destructive techniques, Offline and online condition monitoring, sensors.

UNIT II CONDITION MONITORING OF TRANSFORMERS 9

Diagnostic test chart, Impulse fault analysis, Partial discharge measurements and analysis Conventional diagnostic techniques - Chemical and electrical techniques, Dielectric response measurements in time domain and frequency domain – FRA.

UNIT III CONDITION MONITORING OF SWITCHGEARS 9

Need for monitoring, objectives for switching equipment monitoring, Diagnostic techniques for switching equipment - insulation, current carrying, switching, mechanical operation, control of auxiliary functions.

UNIT IV CONDITION MONITORING OF ROTATING EQUIPMENT 9

Failure modes -Stator and rotor failure mechanisms, Monitoring methods- temperature, chemical, vibration, current, flux, power and discharges

UNIT V FUTURE TRENDS 9

Reaming life analysis, Condition based maintenance and asset management, Introduction to Artificial Intelligence techniques ,latest methodologies and Future trends.

TOTAL : 45 PERIODS

COURSE OUTCOMES

Upon the successful completion of the course, students will:

CO1 aquire knowledge in the different types and methodologies of Condition monitoring practices
CO2 be able to suggest and apply the suitable condition monitoring methods and analyze the condition of Transformers
CO3 be able to suggest and apply the suitable condition monitoring methods and analyze the condition of Switchgear components
CO4 be able to suggest and apply the suitable condition monitoring methods and analyze the condition of Rotating equipment
CO5 aquire knowledge in in future trends and tools for condition monitoring

REFERENCES:

1. R.E.James and Q Su,"Condition Assessment of High Voltage Insulation in Power System Equipment",IET Power and Energy series 53, 2008.
2. Sivaji Chakrovorti, DEbangshuDey, Biswendu Chatterjee," Recent trends in the condition monitoring of transformers", Springer-Verlag, London 2013
3. PeterTavner, Li Ran, Jim Penman and Howard Sedding, 'condition montoring of rotating elelctricalmachines', IETPower and Energy series 56, 2008
4. G C Stone,'ELECTRICAL INSULATION FOR ROTATING MACHINES Design, Evaluation, Aging, Testing, and Repair", IEEE Press

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5. IEEE62, 62-1995 - IEEE Guide for Diagnostic Field Testing of Electric Power Apparatus - Part 1: Oil Filled Power Transformers, Regulators, and Reactors
6. IEC 60599 Interpretation of the analysis of gases in transformers and oil filled equipment in service
7. CIGRE TB No 462, Obtaining Value from On-Line Substation Condition Monitoring
8. CIGRE TB No 558., Guide for the Monitoring, Diagnosis and Prognosis of Large Motors.
9. CIGRE TB No 167, User Guide for the Application of Monitoring and Diagnostic Techniques for Switching Equipment for Rated Voltages of 72.5 kV and above.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	-	2	3
CO2	2	1	2	-	2	3
CO3	2	1	2	-	2	3
CO4	2	1	2	-	3	3
CO5	2	2	2	-	3	3
Average	**2**	**1.4**	**2**	**-**	**2.4**	**3**

HV3003 NANO DIELECTRICS L T P C
3 0 0 3

UNIT I INTRODUCTION TO NANO MATERIALS 9

Introduction to nanomaterials- Definition of nanocomposite, nanofillers, classification of nanofillers, carbon and non-carbon based nanofillers - Properties of nanomaterials- role of size in nanomaterials, nanoparticles, semiconducting nanoparticles, nanowires, nanoclusters, quantum wells, conductivity and enhanced catalytic activity in the macroscopic state

UNIT II PROPERTIES OF NANOMATERIALS 9

Nanocomposites and Properties- Metal-Metal nanocomposites, Polymer-Metalnanocomposites, Ceramic nanocomposites: Dielectric and CMR based nanocomposites. Mechanical Properties, Modulus and the Load-Carrying Capability of Nanofillers, Failure Stress and Strain Toughness, Glass Transition and Relaxation Behavior, Abrasion and Wear Resistance, Permeability, Dimensional Stability Contents, Thermal Stability and Flammability, Electrical and Optical Properties, Resistivity, Permittivity and Breakdown Strength, Refractive Index.

UNIT III SYNTHESIZATION AND CHARACTERIZATION METHODS 9

Synthesis of Nanomaterials by Physical Methods -Inert gas condensation, Arc discharge, Ball Milling, Molecular beam epitaxy-Chemical vapour deposition method and Electro deposition. Chemical methods for Synthesis of Nanomaterials: Chemical precipitation and co-precipitation, Sol-gel synthesis, Microwave heating synthesis, Sonochemical synthesis; Electrochemical synthesis; Photochemical synthesis.
Introduction to microscopy- Scanning Electron Microscopy, Transmission Electron Microscopy, Optical Absorption and Emission Spectroscopy, Thermogravimetric Analysis, Differential Scanning Calorimetry

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UNIT IV NANOCOMPOSITE **9**

Direct Mixing, Solution Mixing, Preparation and characterization of inorganic nanofillersproperties, synthesis, characterization and applications of SiO2, TiO2, ZrO2, Al2O3 and CNTcomposite , Applications of nano filled materials for outdoor and indoor equipments.

UNIT V NANOPOLYMERS **9**

Polymerization, Particle Processing Ceramic/Polymer Composites, Preparation and characterization of Copolymer based nano composites- Barrier properties of polymer nanocomposites- Permeation and diffusion models - Thermo Electric Materials – Applications.

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1 Ability to understand the nano material structure
CO2 Ability to understand the characteristics of nano materials.
CO3 Ability to understand the methods of synthesization and characterization.
CO4 Ability to understand the processing methods of nanocomposite and applications.
CO5 Ability to design and fabricate the electrical insulations with nano dielectric materials.

REFERENCES

1. Handbook of Nanofabrication. Edited by Gary Wiederrcht. Elsevier, 2010.
2. Nanocomposite Science and Technology: by P.M. Ajayan, L.S. Schadler, P.V.Braun, 2003 WILEY-VCH Verlag GmbH Co. KGaA, Weinheim.
3. Nanoporous materials: Advance techniques for characterization, Modeling and Processing Edited by Nick KanelloPoulos. CRC press, 2011.
4. Inorganic Nanoparticles: Synthesis, Application and Perspectives. Edited by Claudia Altavilla and Enrico Ciliberto. CRC Press, 2011.
5. Polymer nanocomposites: by Yiu-Wing Mai and Zhong-Zhen Yu, First published 2006, Woodhead Publishing Limited and CRC Press LLC, USA.
6. CRC Handbook of Thermoelectrics, Ed. CR Rowe.

MAPPING OF COs WITH POs

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

HV3004 APPLICATIONS OF HIGH ELECTRIC FIELDS **L T P C**
3 0 0 3

UNIT I INTRODUCTION 9

Introduction – electrostatic applications- electrostatic precipitation, separation, painting / coating, spraying, imaging, printing, Transport of materials – Sandpaper Manufacture – Smoke particle detector – Electrostatic spinning, pumping, propulsion – Ozone generation – Biomedical applications.

UNIT II APPLICATION IN MICROBIAL INACTIVATION 9

Introduction-definitions, descriptions and applications-mechanisms of microbial in-activations electrical breakdown-electroporation-inactivation models -Critical factors-analysis of process, product and microbial factors-pulse generators –solid state pulse generators. and treatment chamber design -Research needs

UNIT III APPLICATION IN FOOD PRESERVATION 9

Processing of juices, milk, egg, meat and fish products- Processing of water and waste – Industrial feasibility, cost and efficiency analysis

UNIT IV APPLICATION IN CANCER TREATMENT 9

Different types of cancer – Different types of treatments, anti-cancer drugs – Electro-chemotherapy – Electric fields in cancer tissues – Modeling, analysis of cancer tissues

UNIT V SAFETY AND ELECTROSTATIC HAZARDS 9

Introduction – Nature of static electricity – Triboelectric series – Basic laws of Electrostatic electricity– materials and static electricity – Electrostatic discharges (ESD) – Static electricity problems – Hazards of Electrostatic electricity in industry – Hazards from electrical equipment and installations – Static eliminators and charge neutralizers – Lightning protection- safety measures and standards

TOTAL : 45 PERIODS

COURSEOUTCOMES:

CO1: Ability to apply high electric fields in day-to-day life problems
CO2: Ability to apply high electric fields in microbial inactivation
CO3: Ability to preserve food by high electric fields
CO4: Ability to work in multidisciplinary projects like cancer treatment with high electric fields
CO5: Ability to provide safety measures against electrostatic hazards

REFERENCES

1. N.H.Malik, A.A.Ai-Arainy, M.I.Qureshi, “Electrical Insulation in power systems”, Marcel Dekker, inc., 1998.
2. Mazen Abdel-Salam, HussienAnis, Ahdab El-Morshedy, “High Voltage Engineering”, Second Edition, Theory and Practice, Marcel Dekker, Inc. 2000,
3. John D.Kraus, Daniel A.Fleisch, “Electromagnetics with Applications” McGraw Hill International Editions, 1992.
4. Shoait Khan, “Industrial Power System”, CRC Press, Taylor & Francis group, 2008.
5. G.V. Barbosa – Canovas, “Pulsed electric fields in food processing: Fundamental aspects and applications” CRC Publisher Edition March 1 2001.
6. H L M Lelieveld and Notermans.S,et.al., “Food preservation by pulsed electric fields: From research to application”, Woodhead Publishing Ltd. October 2007.
7. Indian Electricity Rules; IS-5216; Electrical Safety Handbook by John Cadick

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MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	1	3	2
CO2	3	2	2	2	3	2
CO3	3	2	2	2	3	2
CO4	3	2	2	3	3	2
CO5	3	2	2	1	2	3
Average	**3**	**1.8**	**2**	**1.8**	**2.8**	**2.2**

HV3051 DESIGN OF SUBSTATIONS **L T P C**
3 0 0 3

UNIT I INTRODUCTION TO AIS AND GIS 9

Introduction – characteristics – comparison of Air Insulated Substation (AIS) and Gas Insulated Substation (GIS) – main features of substations, Environmental considerations, Planning and installation- GIB / GIL

UNIT II MAJOR EQUIPMENT AND LAYOUT OF AIS AND GIS 9

Major equipment – design features – equipment specification, types of electrical stresses, mechanical aspects of substation design- substation switching schemes - single feeder circuits; single or main bus and sectionalized single bus- double main bus-main and transfer bus- main, reserve and transfer bus- breaker-and-a- half scheme-ring bus.

UNIT III INSULATION COORDINATION OF AIS AND GIS 9

Introduction – stress at the equipment – insulation strength and its selection – standard BILs – Application of simplified method – Comparison with IEEE and IEC standards.

UNIT IV GROUNDING AND SHIELDING 9

Definitions – soil resistivity measurement – ground fault currents – ground conductor – design of substation grounding system – shielding of substations – Shielding by ground wires and lightning masts.

UNIT V FAST TRANSIENTS PHENOMENON IN AIS AND GIS 9

Introduction – origin of VFTO - Disconnector switching –– propagation and mechanism of VFTO – VFTO characteristics – Effects of VFTO - Controlling methods

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1: Ability to understand the fundamental components of AIS AND GIS.
CO2 : Ability to understand the layout of AIS and GIS.
CO3 : Ability to understand the insulation coordination of AIS and GIS.
CO4 : Ability to understand the significance of grounding and shielding.
CO5 : Ability to know about the effects of very fast transients in Substations

REFERENCES

1. Andrew R. Hileman, "Insulation coordination for power systems", Taylor and Francis, 1999.
2. M.S. Naidu, "Gas Insulation Substations", I.K. International Publishing House Private Limited, 2008.
3. Klaus Ragallar, "Surges in high voltage networks" Plenum Press, New York, 1980.
4. "Power Engineer's handbook", TNEB Association.
5. Pritindra Chowdhuri, "Electromagnetic transients in power systems", PHI Learning Private Limited, New Delhi, Second edition, 2008.
6. "Design guide for rural substation", United States Department of Agriculture, RUS Bulletin, 1724E-300, June 2001.
7. AIEE Committee Report, "Substation One-line Diagrams," AIEE Trans. on Power Apparatus and Systems, August 1953
8. Hermann Koch, "Gas Insulated Substations", Wiley-IEEE Press,2014
9. IEEE Std 80, IEEE Guide for Safety in AC Substation Grounding - 2013
10. IS Standard 3043 "CODE OF PRACTICE FOR EARTHING (First Revision)"; 1987.
11. Working Group JWG B3.35/CIRED, "Substation earthing system design optimisation through the application of quantified risk analysis" CIGRE 749,2018.
12. CIGRE Green Book, "Substation", Study Committee B3, PP 83 -155.
13. Working Group WG 23.03, "General guidelines for the design of outdoor AC substations. (2nd version)" CIGRE 161, 2000.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	3	1	1	-	1
CO2	1	3	1	1	-	1
CO3	2	3	3	1	-	3
CO4	1	1	1	2	-	1
CO5	3	2	1	2	-	1
Average	**1.6**	**2.4**	**1.4**	**1.4**	**-**	**1.4**

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HV3052 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY **L T 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-linearity 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 Electromagnetic 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.

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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**

HV3005 POLLUTION PERFORMANCE OF POWER APPARATUS AND SYSTEMS **LT P C 3 0 0 3**

UNIT I INTRODUCTION 9
Fundamental process of pollution flashover – development and effect of contamination layer – creepage distance – pollution conductivity – mechanism of pollution flashover – analytical determination of flashover voltage.

UNIT II POLLUTION TESTING 9
Artificial pollution testing – salt-fog method – solid layer method – monitoring of parameters – measurement of layer conductivity – field testing methods., IS/IEC/IEEE Standard

UNIT III POLLUTION PERFORMANCE OF INSULATORS 9
Ceramic and non-ceramic insulators – design of shed profiles – rib factor effect in AC and DC insulators – modelling

UNIT IV POLLUTION PERFORMANCE OF SURGE ARRESTERS 9
External insulation – effect of pollution on the protective characteristics of gap and gapless arresters – modeling of surge diverters under polluted conditions.

UNIT V POLLUTION PERFORMANCE OF INDOOR EQUIPMENT 9
Condensation and contamination of indoor switch gear – performance of organic insulator under polluted conditions – accelerated testing techniques

TOTAL : 45 PERIODS

COURSE OUTCOMES:
CO1 Ability to understand the mechanism and factors affecting the pollution performance
CO2 Ability to design and conduct pollution tests
CO3 Ability to design insulator profile based on pollution
CO4 Ability to understand the external insulation based on pollution
CO5 Ability to design indoor equipment

Attested

REFERENCES

1. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsvier India Pvt. Ltd, 2005.
2. Kind and Karner, “High Voltage Insulation”, Translated from German by Y.Narayana Rao, Frider. Vieweg, &Sohn, Braunschweig, Weishaden, 1985.
3. Air pollution control engineering : second edition - noel de nevers - 2010 - waveland press
4. Klaus Ragaller, “Surges in High Voltage Networks”, Plenum Press, New York, 1980.
5. Looms, J.S.T., “Insulators for High Voltages”, IET, London, U.K 1988.
6. Dieter Kind and Kurt Feser, “High Voltage Test Techniques”, Second Edition, SBA Electrical Engineering Series, New Delhi, 1999.
7. Ravi S. Gorur, “Outdoor Insulators”, Inc. Phoenix, Arizona 85044, USA, 1999
8. Working Group D1.44, “Pollution test of naturally and artificially contaminated insulators” Cigre 201
9. Environmental pollution control engineering - C.S. Rao - 2007 - New age international
10. Working Group C4.303 “OUTDOOR INSULATION IN POLLUTED CONDITIONS - GUIDELINES FOR SELECTION AND DIMENSIONING Part 1: General principles and the AC case” CIGRE 361. 2008

MAPPING OF COs WITH POs

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

PS3151 ANALYSIS AND COMPUTATION OF ELECTROMAGNETIC TRANSIENTS IN POWER SYSTEMS **L T P C**
3 0 0 3

UNIT I REVIEW OF TRAVELLING WAVE PHENOMENA 9

Lumped and Distributed Parameters – Wave Equation – Reflection, Refraction, Behaviour of Travelling waves at the line terminations – Lattice Diagrams – Attenuation and Distortion-switching overvoltage: Short line or kilometric fault, energizing transients - closing and re-closing of lines, methods of control; temporary over voltages: line dropping, load rejection; voltage induced by fault; very fast transient overvoltage(VFTO).

UNIT II PARAMETERS AND MODELLING OF OVER HEADLINES AND UNDER GROUND CABLES 9

Review of line parameters for simple configurations: series resistance, inductance and shunt capacitance; bundle conductors: equivalent GMR and equivalent radius; modal propagation in transmission lines: modes on multi-phase transposed transmission lines, α-β-0 transformation and symmetrical components transformation, modal impedances; analysis of modes on un-transposed lines; effect of ground return and skin effect; transposition schemes; introduction to frequency-dependent line modeling. Distinguishing features of underground cables: technical features, electrical parameters, overhead lines versus underground cables; cable types; series impedance and shunt

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admittance of single- core self-contained cables, impedance and admittance matrices for three phase system formed by three single-core self-contained cables; approximate formulas for cable parameters

UNIT III PARAMETERS AND MODELLING OF TRANSFORMER 9

Transformer modelling guidelines for transient phenomena – Generalization of [R]-[ωL] model single phase N-coil transformer - Generalization of [R]-[ωL]-1 model single phase N-coil transformer- Inverse Inductance Matrix representation of three-phase N-coil transformers- inclusion of exciting current.

UNIT IV INSULATION CO-ORDINATION 9

Insulation co-ordination –volt –time characteristics, Insulation strength and their selection- Evaluation of insulation strength standard BILs-Characteristics of protective devices, applications, location of arresters – insulation co-ordination in AIS and GIS.

UNIT V COMPUTATION OF POWER SYSTEM TRANSIENTS ` 9

Digital computation of line parameters: why line parameter evaluation programs? salient features of a typical line parameter evaluation program; constructional features of that affect transmission line parameters; line parameters for physical and equivalent phase conductors elimination of ground wires bundling of conductors; principle of digital computation of transients: features and capabilities of electromagnetic transients program; steady state and time step solution modules: basic solution methods; case studies on simulation of various types of transients and insulation co-ordination.

TOTAL: 45 PERIODS

COURSE OUTCOMES

Students will be able to:

CO1: Understand and analyse the different types of transients, travelling wave phenomena.
CO2: Model overhead lines and cables and for transient studies.
CO3: Model transformers for transient studies.
CO4: Design a reliable power system with appropriate insulation coordination.
CO5: Compute different types of transients in power systems.

REFERENCES

1. Allan Greenwood, “Electrical Transients in Power System”, Wiley & Sons Inc.New York, 1991.
2. R. Ramanujam, Computational Electromagnetic Transients: Modelling, Solution Methods and Simulation, I.K. International Publishing House Pvt. Ltd, New Delhi -110 016, ISBN 978-93-82332-74-9, 2014; email: info@ikinternational.com
3. PritindraChowdhari, “Electromagnetic transients in Power System”, John Wiley and Sons Inc., Second Edition, 2009.
4. Rakosh Das Begamudre, “Extra High Voltage AC Transmission Engineering”, (Second edition) Newage International (P) Ltd., New Delhi,1990.
5. Naidu M S and Kamaraju V, “High Voltage Engineering”, Tata McGraw-Hill Publishing Company Ltd., New Delhi,2004.
6. Andrew R. Hileman, “Insulation Coordination for Power Systems”, CRC press, Taylor &Francis Group, New York, 1999.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	2	-	3
CO2	2	1	3	2	-	3
CO3	3	1	3	3	3	3
CO4	3	2	2	3	3	3
CO5	3	1	3	2	3	3
Average	**2.6**	**1.25**	**2.8**	**2.4**	**3**	**3**

Attested

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.
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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.

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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**

PS3051 COMPUTATIONAL INTELLIGENCE TECHNIQUES TO POWER SYSTEMS **L T P C 3 0 0 3**

UNIT I ARTIFICIAL NEURAL NETWORKS (ANN) 9

Introduction to Artificial Neural Networks - Definition and Fundamental concepts - Biological Neural Network – Modeling of a Neuron -Activation functions – initialization of weights - Typical architectures-Leaning/Training laws - Supervised learning Unsupervised learning – Reinforcement learning-Perceptron – architectures-Linear Separability – Multi – layer perceptron using Back propagation Algorithm (BPA) – Application to Load forecasting.

UNIT II DEEP LEARNING 9

Introduction to deep neural networks - loss functions and optimization - regularization methods - convolutional neural networks - transfer learning- recurrent neural networks - long short-term memory and gated recurrent unit - deep belief network - Maximum Power Point Tracking of PV Grids using Deep Learning.

UNIT III FUZZY LOGIC 9

Introduction – Fuzzy versus crisp – Fuzzy sets – Membership function – Basic Fuzzy set operations – Properties of Fuzzy sets – Fuzzy cartesian Product – Operations on Fuzzy relations – Fuzzy logic – Fuzzy Quantifiers – Fuzzy Inference – Fuzzy Rule based system – Defuzzification methods – Application to Load frequency control and Reactive power control.

UNIT IV GENETIC ALGORITHM AND PARTICLE SWARM OPTIMIZATION 9

Genetic algorithms- Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators -Bird flocking and Fish Schooling – anatomy of a particle- equations based on velocity and positions -PSO topologies - control parameters- Application to Economic load dispatch.

UNIT V MULTI OBJECTIVE OPTIMIZATION 9

Introduction- Concept of Pareto optimality - Non-dominant sorting technique-Pareto fronts-best compromise solution-min-max method-NSGA-II algorithm and application to general two objective optimization problem - Application to combined economic emission dispatch.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

CO1: analyze functional operation of a ANN and their bio-foundations
CO2: analyze functional operation of deep neural networks
CO3: design and develop fuzzy logic for simple control applications
CO4: design and develop genetic algorithms and particle swarm optimization for simple systems
CO5: solve multi-objective optimization problems to obtain Pareto fronts

REFERENCES

1. Sridhar S., and Vijayalakshmi M., "MACHINE Learning", Oxford University Press, First Edition, 2021.
2. Rajasekaran S. and Pai G.A.V., “Neural Networks, Fuzzy Logic & Genetic Algorithms”, PHI, New Delhi, 2008.
3. Kalyanmoy Deb, “Multi-Objective Optimization using Evolutionary Algorithms”, John Wiley & Sons, 2001.
4. Kothari, D.P. and Dhillon, J.S., “Power system optimization”, Second Edition, PHI Learning Private Limited, 2010.
5. Weerakorn Ongsakul and Vo Ngoc Dieu, “Artificial Intelligence in Power System Optimization”, CRC Press, 2013.

MAPPING OF COs WITH POs

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

PS3251 RESTRUCTURED POWER SYSTEM L T P C
3 0 0 3

UNIT I INTRODUCTION 9

Deregulation of power industry, unbundling of electric utilities, Issues involved in deregulation – Fundamentals of Economics: Consumer and suppliers behavior, Total utility and marginal utility, Law of diminishing marginal utility, Elasticity of demand and supply curve, Market equilibrium, Consumer and supplier surplus, Global welfare, Deadweight loss - The Philosophy of Market Models: Monopoly model, Single buyer model, Wholesale competition model, Retail competition model, distinguishing features of electricity as a commodity, pillars of market design- Market power.

UNIT II TRANSMISSION CONGESTION MANAGEMENT 9

Importance of congestion management in deregulated environment - Classification of congestion management methods - Calculation of ATC - Non-market methods - Market based methods - Nodal pricing - Inter-zonal Intra-zonal congestion management - Price area congestion management - Capacity alleviation method.

UNIT III LOCATIONAL MARGINAL PRICES (LMP) AND FINANCIAL TRANSMISSION RIGHTS 9

Fundamentals of locational marginal pricing - Lossless DCOPF model for LMP calculation - Loss compensated DCOPF model for LMP calculation - ACOPF model for LMP calculation - Risk Hedging Functionality Of financial Transmission Rights - FTR issuance process - Treatment of revenue shortfall - Secondary trading of FTRs - Flow Gate rights - FTR and market power

UNIT IV ANCILLARY SERVICE MANAGEMENT AND PRICING OF TRANSMISSION NETWORK 9

Types of ancillary services - Load-generation balancing related services - Voltage control and reactive power support services - Black start capability service - Mandatory provision of ancillary services - Markets for ancillary services - Co-optimization of energy and reserve services - International comparison. Pricing of transmission network: wheeling - principles of transmission pricing - transmission pricing methods - Marginal transmission pricing paradigm - Composite pricing paradigm - loss allocation methods

UNIT V MARKET EVOLUTION 9

US markets: PJM market, Nordic power market, California energy market - Reforms in Indian power sector: Framework of Indian power sector, Reform initiatives, availability based tariff (ABT), The Electricity Act 2012, Open Access issues, Power exchange, role of RLDC, NLDC and ALDC.

TOTAL: 45 PERIODS

COURSE OUTCOMES

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

CO1: Understand the process of restructuring of power industry and analyze the philosophy of market models
CO2: analyze various methods of congestion management in deregulated power system
CO3: analyze the locational marginal pricing and financial transmission rights
CO4: analyze the ancillary service management and wheeling charges
CO5: explain the evolution of Indian and US power markets

REFERENCES

1. Mohammad Shahidehpour, MuwaffaqAlomoush,“Restructured electrical powersy stems: operation, trading and volatility” Marcel Dekker Pub.,2001.
2. Kankar Bhattacharya, Math H.J.Boolen, and JaapE.Daadler, "Operation of restructured power systems”, Kluwer Academic Pub.,2001.
3. Sally Hunt, "Making competition work in electricity”, John Willey and Sons Inc. 2002.
4. Steven Stoft, " Power System Economics: Designing Markets for Electricity”, Wiley-IEEE Press, 2002.
5. S.A. Khaparde, A.R. Abhyankar, "Restructured Power Systems", NPTEL Course, https://nptel.ac.in/courses/108101005/.

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MAPPING OF COs WITH POs

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

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.

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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**	-	-

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. NadarajahMithulananthan, Duong Quoc Hung, Kwang Y. Lee, “Intelligent Network Integration of Distributed Renewable Generation”, Springer International Publishing, Switzerland, 2017.
6. Ali K., M.N. Marwali, Min Dai, “Integration of Green and Renewable Energy in Electric Power Systems”, Wiley and sons, New Jersey, 2010.

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**

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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

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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.

Attested

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**

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

Attested

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**

PW3252 OPTIMIZATION TECHNIQUES FOR ENERGY MANAGEMENT **L T P C**
3 0 0 3

UNIT I PROBABILITY THEORY 9

The nature of random variables: populations and samples, parameters and statistics - Probability concepts: properties of random variables, probability distribution functions.

UNIT II DEMAND ANALYSIS AND FORECASTING 9

Drivers of energy demand - Sectoral energy demand: domestic, commercial, industrial, agriculture - Projections for future demands – Guidelines for Medium and Long-Term Power Demand Forecast – Time-Series and Machine Learning Methods.

UNIT III INTRODUCTION TO OPTIMIZATION 9

Problem formulation: decision variables, objective function, maxima and minima constraints - Analysis techniques: simulation, optimization and stochastic optimization - Multi-objective optimization - non-inferior solutions, trade off analysis, weighted and constraints method.

UNIT IV LINEAR PROGRAMMING AND APPLICATION 9

Assumptions, problems formulation and solutions, graphical methods, simplex algorithm, duality concept, sensitivity analysis -Power system planning using optimization techniques - case study.

UNIT V DYNAMIC PROGRAMMING AND APPLICATION 9

Introduction, multi stage decision problems, recursive equations, principle of optimality, discrete dynamic programming - Optimal energy resource, technology mix in micro and macro level energy planning exercises - Power generation expansion planning - case study.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

CO1: Define and use optimization techniques and concepts.

CO2: Understand the concept of optimization methods for energy system planning

CO3: Define an optimization problem and exploring the solution by applying optimization methods and interpreting results.

CO4: Excel the selection of optimization techniques for real time problems and to analyze the solutions.

CO5: Analyze the various operating modes of different configurations in different applications.

REFERENCES:

1. Taha, H. A.,"Operations Research—an Introduction", Tenth Edition, Pearson Education, 2019.
2. Vohra, N. D.,"Quantitative Techniques in Management", Fifth Edition, Tata McGraw-Hill Education, 2017.
3. Rardin, R. L.,"Optimization in operations research: Upper Saddle River", Second Edition, Pearson, 2017.
4. Dhillon, J. S., and Kothari, D. P,"Power system optimization", Second Edition, PHI Learning Private Limited, 2010.
5. Ayyub B.M., McCuen R.H., "Probability, Statistics and Reliability for Engineers and Scientists", Third Edition, CRC Press, 2011.

MAPPING OF COs WITH POs

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

Attested

PW3251 **ENERGY STORAGE SYSTEMS** **L T 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.

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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**

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 Attested **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**	**-**

Attested

PW3058 WASTE TO ENERGY CONVERSION **LT P C**
3 0 0 3

UNIT I WASTE SOURCES AND CHARACTERIZATION 9

Introduction - Principles of Waste Management and Waste Utilization, Waste Management Hierarchy - 3R Principle: Reduce, Reuse and Recycle – Waste Production in Domestic, Industrial and Agriculture Sectors - Classification of Waste: Agro based, Forest Residues, Domestic Waste, Industrial Waste (Hazardous and Non-Hazardous) – Characterization of Waste for Energy Utilization – Waste Selection Criteria

UNIT II TECHNOLOGIES FOR WASTE TO ENERGY CONVERSION 9

Biomass Resources and their Classification - Types of Biogas Plants – Biogas Plant Technology and Status - Biomass Conversion Technology: Combustion and Incineration, Biochemical Conversion (Energy Production through Anaerobic Digestion and Fermentation), Thermochemical Conversion (Combustion, Pyrolysis, Gasification, Liquefaction) – Waste to Energy Plasma Arc Gasification (PAG) Technology - Biomass Energy Programme in India

UNIT III BIOMASS GASIFIERS, PYROLYSIS AND BIOMASS HANDLING 9

Gasifiers: Fixed-Bed/Moving-Bed Gasifier – Updraft, Downdraft, Fluidized-Bed Gasifier – Plasma Gasification - Construction and Operation Pyrolysis – Types of Pyrolysis: Slow Pyrolysis, Fast Pyrolysis – Pyrolysis Product Types: Solid, Liquid and Gas Biomass Handling – Introduction – Design of a Biomass Energy System – Biomass-Handling System: Receiving – Storage and Screening-Feed Preparation-Conveying-Feeding

UNIT IV WASTE TO ENERGY OPTIONS AND ENVIRONMENTAL IMPLICATIONS 9

Landfill Gas, Collection and Recovery - Refuse Derived Fuel (RDF) - Solid Recovered Fuel (SRF) - Energy from Plastic Wastes: Non-Recyclable Plastic Wastes for Energy Recovery – Energy from Rubber Wastes - Benchmarking and Standardization of Energy Recovery from Waste – Environmental Standards for Waste to Energy Plant Operations – Carbon Credits: Carbon Foot Calculations and Carbon Credit Transfer Mechanism

UNIT V CENTRALIZED AND DECENTRALIZED WASTE TO ENERGY PLANTS 9

Waste Activities: collection, segregation, transportation and storage requirements - Location and Siting of Waste to Energy plants - Industry Specific Applications: Sugar, Pulp and Paper, Refinery and Petrochemical Industry - Centralized and Decentralized Energy Production for Municipal Solid Waste (MSW) - Comparison of Centralized and decentralized systems and its operations – Case Studies: Success and Failures of Indian Waste to Energy Plants

TOTAL = 45 PERIODS

COURSE OUTCOMES:

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

CO1: Understand the various types of wastes from which energy can be generated and characterization of waste for energy utilization

CO2: Gain knowledge on the various technologies for waste to energy conversion

CO3: Develop knowledge on various types of biomass gasifiers and their operations, types of pyrolysis process and Biomass handling

CO4: Gain knowledge on waste to energy conversion options, environmental standards for waste to energy plant operations and Carbon Credit Mechanism

CO5: Understand the principles of Centralized and Decentralized Waste to Energy Production plants through case studies.

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REFERENCES:

1. Khandelwal, K. C. and Mahdi, S. S.," Biogas Technology - A Practical Hand Book - Vol. I & II", Tata McGraw Hill Publishing Co. Ltd., 1983
2. C. Y. WereKo-Brobby and E. B. Hagan," Biomass Conversion and Technology", John Wiley & Sons, 1996
3. Shobh Nath Singh, "Non-Conventional Energy Resources", Pearson India, 2015
4. Tchobanoglous, George, and Frank Kreith," Handbook of Solid Waste Management", 2nd Edition: McGraw-Hill, New York,2002
5. Paul Breeze," Energy from Waste (Power Generation)", First Edition, Academic Press, 2017
6. Banwari Lal and Pratwardhan," Wealth from Waste: Trends and Technologies", TERI Press
7. S.N.Mukhopadhyay, "Fundamentals of Waste and Environmental Engineering", TERI Press
8. "Industrial and Urban Waste Management in India", TERI Press
9. Report of the Task Force on Waste to Energy, Niti Ayog (Formerly Planning Commission), 2014, Source: www. swachhbharaturban.gov.in/Task Force Report on WTE
10. Prabir Basu, "Biomass Gasification and Pyrolysis- Practical Design", Academic Press,2010

MAPPING OF COs WITH POs

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

PW3055 IOT FOR SMART POWER SYSTEMS L T P C
3 0 0 3

UNIT I INTRODUCTION 9
Evolution of Internet of Things (IoT) –Definitions and Characteristics – Technologies for IoT– Sensors, Actuators and its types –Basics of Web Service and CLOUD Computing - Big data analytics - Importance of IoT in power systems - IoT standards

UNIT II IOT ARCHITECTURE AND PROTOCOLS 9
IoT Architecture – Layers – Protocol: SCADA, RFID – Internet of Energy (IoE) architecture and its requirements for Power Systems - IoT communication topologies for power system application

UNIT III IOT FOR SMART GRID 9
Integration of Internet of Things (IoT) into Smart Grid (SG) – Smart Grid Architectures: Four layered IoT, Web-enabled SG Architecture - Big Data and Cloud for IoT aided SG system- Sensors for Smart Power Grids: Smart Metering and Grid Configuration- Synchronization of Current and Voltage Transducers - Phasor Measurement Units (PMU) - Sending Sensor data over the internet - Cyber Security for Smart Grid

UNIT IV IOT BASED SMART MONITORING SYSTEMS 9

Infrastructure for Smart Metering – Energy Efficiency in Residential, Commercial Buildings – Smart Power Quality Monitoring – Transformer Monitoring System - Smart Monitoring for EV Charging Infrastructure-Case studies

UNIT V IOT FOR ENERGY MANAGEMENT 9

Smart Energy Management – Cyber Physical Systems – Smart Electricity Management – Demand Side Management-Case Studies

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

CO1: Gain knowledge about various IoT technologies and its importance in power system

CO2: Able to analyze different IoT architectures and communication topologies for power system applications

CO3: Understand IoT for Smart Grid

CO4: Attain knowledge about various IoT based smart monitoring systems

CO5: Apply IoT for Energy Management

REFERENCES:

1. Raj Kamal, “Internet of Things Architecture and Design Principles”, McGraw Hill Education (India) Private Limited, Second Edition, 2022.
2. Kostas Siozios, Dimitrios Anagnostos, Dimitrios Soudris, “IoT for Smart Grids: Design Challenges and Paradigms”, First Edition, Springer, 2019.
3. Pawan Kumar, Srete Nikolovski, Z Y Dong, “Internet of Energy Handbook”, 1st Edition, CRC Press, 2021.
4. Sharmeela C, Sanjeevikumar P, Sivaraman P, Meera Joseph, “IoT, Machine Learning and Blockchain Technologies for Renewable Energy and Modern Hybrid Power Systems”, First Edition, River Publishers, 2023.
5. Vahid Vahidinasab, Behnam Mohammadi-Ivatloo, “Electric Vehicle Integration via Smart Charging Technology, Standards, Implementation, and Applications”, First Edition, Springer, 2022.
6. Mohammadreza, Behnam, Kazem Zare, Amjad, "IoT Enabled Multi-Energy Systems", First Edition, Academic Press, 2023
7. O.V.Gnana Swathika, K.Karthikeyan, P.Sanjeevikumar,”IoT Analytics and Renewable Energy Systems - Vol. 1 and Vol.2”, First Edition, CRC Press, 2023

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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PW3057 RENEWABLE ENERGY TECHNOLOGY LT P C
3 0 0 3

UNIT I INTRODUCTION 9

Renewable Energy Sources Vs Non-Renewable Energy Sources - Global Renewable Energy (RE) Availability - RE Resources available in India: Current Generation and utilization of RE Resources in India - Potential of Renewable Energy in Power Production and Need for Renewable Energy Technology – Non-Conventional Energy (NCE) for Rural India – NCE and Cost.

UNITII SOLAR ENERGY 9

Solar Radiation and its measurements - Solar Thermal Energy Conversion from Solar Plate Collectors and Concentrating Collectors (CC) – CC : Types – Classification –Applications of Solar Thermal Energy: Solar Water Heating system - Direct Solar Electricity Conversion from Photovoltaics - Types of Solar Cells – Solar Photovoltaic (SPV) Systems: On-grid and Off-grid SPV System - Applications: Domestic Lighting, Solar Street Lighting, Rural Irrigation, Solar Powered Refrigerator - Building Integrated Photovoltaic (BIPV) – Building Adaptive Photovoltaic (BAPV)

UNIT III WIND ENERGY 9

Basic Principle of Wind Generation – Wind Data and Analysis - Principle of Wind Power Generation - Wind Site and its Resource Assessment - Wind Mills and Sub-Systems – Classification of Wind Turbines – Operating Characteristics of Wind-Mill – Wind Turbine Controls for Wind Power Plants (WPPs) : Stand-alone Mode – Grid Connected Wind Turbine Generator (GWTG) - Hybrid Systems – WPP Control Overview - Wind Power Plant (WPP) Control Strategies: FGS-FP, FGS-VP,VGS-FP and VGS-VP - Classification of Wind Power Plants (WPPs): Type-A WPP, Type-B WPP, Type-C WPP and Type-D WPP – Environmental Impact of Wind Energy

UNIT IV BIOENERGY 9

Biomass Resources - Biomass Conversion Technologies and their classification, Biogas Generation: Principle - Different Biogas Digesters: Floating Drum Type and Fixed Dome Type – Power Generation Systems using Biofuels: Power Generation from Biogas and Power Generation using Liquid Waste – Biomass Cogeneration Systems

UNIT V OTHER TYPES OF ENERGY 9

Energy Conversion from Hydrogen and Fuel cells, Introduction to Geothermal Energy - Mining of Geothermal Heat – Geothermal Field – Geothermal Resources – Environmental Impact from extracting Geothermal Energy - Geothermal potential in India – Ocean Thermal Energy Conversion Systems (OTEC): Historical Review – Principle - Different OTEC Systems – Details of OTEC Plant Components – Location and Environmental Impact of OTEC plants - Tidal Energy: Introduction – Working of the Tidal Plant -Layout of a typical Tidal Power House – Major problem associated with Tidal Plants – Wave Energy : Introduction – Wave and Wave Generation – Ocean Wave Parameters – Wave Energy Conversion Devices – Environmental Effects of Wave Energy

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

CO1: Gain knowledge about the Renewable Energy (RE) Resource potential available in India as well as global RE scenario and need for RE Technology.

CO2: Understand the basics of Solar radiation, Solar Thermal Energy Conversion and SPV systems.

CO3: Understand the concepts of various Wind Energy Conversion System.

CO4: Gain knowledge about Bioenergy and Biomass Conversion Technologies.

CO5: Gain knowledge about energy conversion technologies for harnessing the energy from other RE resources such as Hydrogen, Fuel Cell, Geothermal, OTEC, Wave Energy and Tidal Energy.

REFERENCES:

1. Twidell and Wier," Renewable Energy Resources", CRC Press, 2010.
2. Tiwari and Ghosal," Renewable Energy Resources", Narosa Publishing India, 2015.
3. B.H.Khan, "Non – Conventional Energy Resources", Tata Mc Graw Hill, 2006.
4. V.M.Domkundwar, A.V.Domkundwar, "Solar Energy and Non-Conventional Energy Sources", Dhanpat Rai & Co. Pvt. Ltd., India, 2018.
5. D.P.Kothari, K.C.Singhal, "Renewable Energy Sources and Emerging Technologies", Prentice Hall, India, 2015.
6. D.S.Chauhan, S.K. Srivastava, "Non – Conventional Energy Resources", New Age Publishers, 2006.

MAPPING OF COs WITH POs

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

PW3053 ENERGY EFFICIENT BUILDINGS LT P C
3 0 0 3

UNIT I CLIMATE AND SHELTER 9

Historic buildings – Modern architecture – Examples from different climate zones –Thermal comfort – Solar geometry and shading – Energy modeling techniques– Integrative Modeling methods and building simulation.

UNIT II PRINCIPLES OF ENERGY CONSCIOUS BUILDING DESIGN 9

Energy conservation in buildings – Day lighting – Solar based Water heating - Advances in thermal insulation – Heat gain/loss through building components - Solar architecture.

UNIT III PASSIVE SOLAR HEATING 9

Basics of Passive solar – Mechanical Systems – South Facing Glass – Thermal mass – Orientation – site planning for solar access - Direct gain – thermal storage wall – Sunspace –Passive cooling – Ventilation - Radiation – Evaporation and Dehumidification – Design guidelines and natural cooling guidelines.

UNIT IV ENERGY CONSERVATION IN BUILDING 9

Air conditioning – HVAC equipment's – Computer packages for thermal design of buildings and performance prediction – Monitoring and instrumentation of passive buildings – Control systems for energy efficient buildings – Illustrative passive buildings – Integration of emerging technologies –

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Intelligent building design principles – ECBC applicability – Building Envelope – Comfort system and controls – Lighting – Electrical Power and Renewable Energy.

UNIT V EFFICIENT TECHNOLOGIES IN ELECTRICAL SYSTEMS 9

Maximum Demand Controller, Automatic Power Factor Controller, Energy Efficient Motor – Energy Efficient Lighting System and Energy Efficient Transformers.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

CO1: Understand the different climate zones and modelling methods.
CO2: Design energy conscious building.
CO3: Understand the concepts of Passive Solar Heating (PSH) and design guidelines for PSH.
CO4: Gain knowledge about the energy conservation techniques in buildings.
CO5: Know about different energy efficient technologies for electrical system.

REFERENCES:

1. Joseph Clarke, “Energy Simulation in Building Design”, II Edition, Butterworth, 2001
2. J. K. Nayak and J. A. Prajapati, “Handbook on Energy Conscious Buildings”, Solar Energy Centre, MNES, May 2006
3. “Energy Conservation Building Codes Guide Book”, 2017
4. “Passive Solar Building - Design Strategies”, Guidelines for Home Passive Solar Industries Council, National Renewable Energy Laboratory, USA, 2001
5. J. Douglas Batcomb, “Passive Solar Building”, The MIT Press, 1992
6. Thomas H.Kuehn, James W. Ramsey and J. L. Threlkeld, “Thermal Environmental Engineering”, 3rd Edition, Prentice Hall, 1970
7. Zhiqiang John Zhai, “Energy Efficient Buildings: Fundamentals of Building Science and Thermal Systems”, 1st Edition, Wiley, 2022
8. David S-K. Ting, Rupp Carriveau, “Energy Generation and Efficiency Technologies for Green Residential Buildings (Energy Engineering)”,IET, 2019

MAPPING OF COs WITH POs

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

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PW3056 MICRO GRID OPERATION AND CONTROL **LT P C**
3 0 0 3

UNIT I MICRO SOURCES AND STORAGE 9

Microgrid Structure and Operating Modes – Solar PV – Wind Energy – Fuel Cell –Battery – Super capacitor.

UNIT II 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

UNIT III 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 IV HYBRID MICROGRID 9

Hybrid AC/DC Microgrid Structure: AC Coupled, DC Coupled, AC-DC Coupled –Control Strategies: Different modes of operation during transition – Simulation Studies

UNIT V MICROGRID PROTECTION 9

Protection: Effect on Relay Protection of distribution network, Differential Relay Protection, Directional Impedance Relay Protection– Islanding: Active and Passive Techniques– Earthing: Requirements, Earthing mode of DG in TN/TT Earthing System, Earthing mode of DG in IT

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon the successful completion of the course, students will be able to:
CO1: Analyze micro-sources and storage systems.
CO2: Analyze the configurations and control aspects of AC microgrid.
CO3: Understand and analyze the configurations and control aspects of DC microgrid.
CO4: Acquire knowledge about configurations and control aspects of Hybrid microgrid.
CO5: Learn the protection aspects of microgrid.

REFERENCES:

1. H. Bevrani, Bruno Francois and ToshifumiIse, “Microgrid Dynamics and Control”, Wiley, 2017.
2. Li Fusheng, Li Ruisheng and Zhou Fengquan, “Microgrid Technology and Engineering Application”, Elsevier, 2016.
3. M.S. Mahmoud, “Microgrid - Advanced Control Methods and Renewable Energy System Integration”, Elsevier, 2017.
4. Farzam Nejabatkhah and Yun Wei Li, “Overview of Power Management Strategies of Hybrid AC/DC Microgrid”, IEEE Transactions on Power Electronics, 2014.
5. Papai Ray, Monalisa Biswal, “Microgrid: Operation, Control, Monitoring and Protection”, Springer Singapore, 2020.

MAPPING OF COs WITH POs

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

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

UNIT I HYBRID ELECTRIC VEHICLE ARCHITECTURE AND POWER TRAIN COMPONENT 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).

Attested

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**

PE3151 ANALYSIS OF POWER CONVERTERS LT 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**

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
ntroduction - 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**	**-**	**-**

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

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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**	**-**

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PE3252 SPECIAL ELECTRICAL MACHINES

L T 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**

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. I.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**

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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**	**-**

CO3057 OPTIMAL CONTROL AND FILTERING **LT P C**
3 0 0 3

UNIT I INTRODUCTION 9

Statement of optimal control problem – Problem formulation and forms of optimal Control– Selection of performance measures. Necessary conditions for optimal control – Pontryagin's minimum principle – State inequality constraints – Minimum time problem.

UNIT II LINEAR QUADRATIC TRACKING PROBLEMS 9

Linear tracking problem – LQG problem – Computational procedure for solving optimal control problems – Characteristics of dynamic programming solution – Dynamic programming application to discrete and continuous systems – Hamilton Jacobi Bellman equation.

UNIT III NUMERICAL TECHNIQUES FOR OPTIMAL CONTROL 9

Numerical solution of 2-point boundary value problem by steepest descent and Fletcher Powell method - solution of Ricatti equation by negative exponential and interactive Methods

UNIT IV FILTERING AND ESTIMATION 9

Filtering – Linear system and estimation – System noise smoothing and prediction – Gauss Markov discrete time model – Estimation criteria – Minimum variance estimationLeast square estimation – Recursive estimation.

UNIT V KALMAN FILTER AND PROPERTIES 9

Filter problem and properties – Linear estimator property of Kalman Filter – Time invariance and asymptotic stability of filters – Time filtered estimates and signal to noise ratio improvement – Extended Kalman filter.

TOTAL: 45 PERIODS

COURSE OUTCOMES

Ability to

CO1 : Understand the concept of Optimal Control problem.

CO2 : Identify, Formulate and measure the performance of Optimal Control.

CO3 : understand the Linear Quadratic Tracking Problems and implement dynamic programmingapplication for discrete and continuous systems.

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CO4 : Solve Numerical solution of 2-point boundary value problem by steepest descent andFletcher Powell method.

CO5 : Understand Filtering problem their properties, linear estimator property of Kalman Filter andTime invariance and asymptotic stability of filters.

REFERENCES:

1. KiRk D.E., 'Optimal Control Theory – An introduction', Prentice hall, N.J., 1970.
2. Sage, A.P., 'Optimum System Control', Prentice Hall N.H., 1968.
3. Anderson, BD.O. and Moore J.B., 'Optimal Filtering', Prentice hall Inc., N.J., 1979.
4. S.M. Bozic, "Digital and Kalman Filtering", Edward Arnould, London, 1979.
5. Astrom, K.J., "Introduction to Stochastic Control Theory", Academic Press, Inc, N.Y., 1970.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	-	2	2	-	-
CO2	-	-	1	2	-	-
CO3	-	1	3	1	-	-
CO4	3	2	1	1	-	-
CO5	1	1	2	2	-	-
AVg.	**1.7**	**1.3**	**1.8**	**1.6**	**-**	**-**

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

CO3152 INTELLIGENT CONTROLLERS **L T 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.

Attested

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

CO3051 BIOMEDICAL INSTRUMENTATION L T P C
3 0 0 3

UNIT I BIOMEDICAL MEASUREMENTS AND SAFETY CONSIDERATIONS 9
Physiological systems and measurable variables- Nature and complexities of biomedical measurements- Medical equipment standards- organization, classification and regulation- Biocompatibility - Human and Equipment safety — Physiological effects of electricity, Micro and macro shocks, thermal effects.

UNIT II MODELING AND SIMULATION IN BIOMEDICAL INSTRUMENTATION 9
Modeling and simulation in Biomedical instrumentation – Difference in modeling engineering systems and physiological systems — Model based analysis of Action Potentials - cardiac output – respiratory mechanism - Blood glucose regulation and neuromuscular function.

UNIT III CLASSIFICATION OF BIOLOGICAL SIGNALS 9
Types and Classification of biological signals – Signal transactions – Noise and artifacts and their management - Biopotential electrodes- types and characteristics - Origin, recording schemes and analysis of biomedical signals Electrocardiography(ECG), with typical examples of and Electroencephalography(EEG), Electromyography (EMG)– Processing and transformation of signals- applications of wavelet transforms in signal compression and denoising.

UNIT IV IMAGING MODALITIES AND ANALYSIS 9
Advanced medical imaging techniques and modalities -Instrumentation and applications in monitoring and diagnosis- Computed tomography, Magnetic Resonance Imaging and ultrasound- Algorithms and applications of artificial intelligence in medical image analysis and diagnosis-Telemedicine and its applications in tele monitoring.

UNIT V IMPLANTABLE MEDICAL DEVICES 9
Artificial valves, vascular grafts and artificial joints- cochlear implants - cardiac pacemakers – Microfabriation technologies for biomedical Microsystems- microsensors for clinical applications – biomedical microfluid systems

TOTAL : 45 PERIODS

COURSE OUTCOMES
On completion of this course, the students will be able to
CO1: Gain a comprehensive understanding of physiological systems, biomedical measurements, and the critical aspects of safety in medical equipment
CO2: Create mathematical models for various physiological systems, allowing for in-depth analysis and simulation of complex biomedical phenomena.
CO3: Manage noise and artifacts, utilizing biopotential electrodes, and applying signal processing techniques, including wavelet transforms, to biomedical signals.
CO4: Understand the applications and benefits of artificial intelligence in medical image analysis and diagnosis, along with the potential of telemedicine in enhancing healthcare through remote monitoring and consultations.
CO5: Understand the various implantable biomedical devices and microsystems.

REFERENCES

1. John G.Webster, “Bioinstrumentation”, John Wiley & Sons, 2008.
2. Shayne C.Gad, “Safety Evaluation of Medical Devices”, CRC Press, Second Edition, 2002.
3. Michael C.K.Khoo, “Physiological Control Systems: Analysis, Simulation and Estimation,IEEE Press, 2000.
4. John G.Webster, “Medical Instrumentation Application and Design”, John Wiley

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& Sons,Third Edition, 2009.
5. L.Cromwell, Fred J.Weibell and Erich A.Pfeiffer, “Biomedical Instrumentation andMeasurements”, Prentice Hall of India, Digitized 2010.
6. P.Strong, “Biophysical Measurements”, Tektronix, Digitized 2007.
7. K.Najarian and R. Splinter, “Biomedical Signal and Image Processing”, CRC Press, 2012.
8. John L.Semmlow, “Biosignal and Biomedical Image Processing”, CRC Press, First Edition,2004.
9. Joseph J.Carr and John M.Brown, “Introduction to Biomedical Equipment Technology”,Prentice Hall, Fourth Edition, 2004.

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
AVg.	**3**	**3**	**3**	**-**	**-**	**3**

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

CO3056 MULTI SENSOR DATA FUSION LT P C
3 0 0 3

UNIT I MULTISENSOR DATA FUSION INTRODUCTION 9
sensors and sensor data, Use of multiple sensors, Fusion applications. The inference hierarchy: output data. Data fusion model. Architectural concepts and issues. Benefits of data fusion, Mathematical tools used: Algorithms, co-ordinate transformations, rigid body motion. Dependability and Markov chains, Meta – heuristics.

UNIT II ALGORITHMS FOR DATA FUSION 9
Taxonomy of algorithms for multisensor data fusion. Data association. Identity declaration.

UNIT III ESTIMATION: 9
Kalman filtering, practical aspects of Kalman filtering, extended Kalmal filters. Decision level identify fusion. Knowledge based approaches.

UNIT IV ADVANCED FILTERING 9
Data information filter, extended information filter. Decentralized and scalable decentralized estimation. Sensor fusion and approximate agreement. Optimal sensor fusion using range trees recursively. Distributed dynamic sensor fusion.

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UNIT V HIGH PERFORMANCE DATA STRUCTURES: 9

Tessellated, trees, graphs and function. Representing ranges and uncertainty in data structures. Designing optimal sensor systems within dependability bounds. Implementing data fusion system.

TOTAL : 45 PERIODS

COURSE OUTCOMES

CO1 : Ability to explain and use multiple sensor data in data fusion model.
CO2 : Capable to use algorithms for data fusion.
CO3 : Ability to estimate using kalman filter.
CO4 : Ability to estimate using advance filtering such as data, extended information filtering.
CO5 : Ability to handle various high performance data structures.

REFERENCES:

1. David L. Hall, Mathematical techniques in Multisensor data fusion, Artech House, Boston,1992.
2. R.R. Brooks and S.S. Iyengar, Multisensor Fusion: Fundamentals and Applications withSoftware, Prentice Hall Inc., New Jersey, 1998.
3. Arthur Gelb, Applied Optimal Estimation, The M.I.T. Press, 1982.
4. James V. Candy, Signal Processing: The Model Based Approach, McGraw –Hill BookCompany, 1987.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	-	-	-	3	2	2
CO2	1	-	1	2	2	3
CO3	1	2	1	-	-	-
CO4	1	2	1	-	-	-
CO5	-	-	-	1	1	2
Average	**1**	**2**	**1**	**2**	**1.66**	**2.33**

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

Attested

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CO3251 MODERN AUTOMATION SYSTEMS L T P C
3 0 0 3

UNIT I INTRODUCTION TO AUTOMATION 9

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

UNIT II PLC 9

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

UNIT III DCS AND SCADA 9

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

UNIT IV VIRTUAL INSTRUMENTATION 9

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

UNIT V INDUSTRIAL INTERNET OF THINGS 9

INDUSTRIAL INTERNET OF THINGS: Introduction – Architecture – Sensing, communication – Big data analytics – Security and Fog computing, cloud computing- Internet for energy – Case Study

TOTAL: 45 PERIODS

COURSE OUTCOMES:

In the end of the course the students will be:
CO1: able to gain the knowledge on fundamentals of automation.
CO2: able to understand the concepts of PLC, DCS and SCADA
CO3: able to understand Virtual Instrumentation for engineering processes.
CO4: able to gain the knowledge on Industrial Internet of Things
CO5: able to apply the concepts and develop automation for different systems.

REFERENCES:

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

Attested

MAPPING OF COs WITH POs

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

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

ET3151 DESIGN OF EMBEDDED SYSTEMS LT P C

3 0 0 3

UNIT I INTRODUCTION TO EMBEDDED SYSTEMS 9

Selection of Single-processor Architectures & Multi-Processor Architectures-built in features for embedded Target Architecture -Embedded Coprocessors-DMA- memory devices – Memory management methods-memory mapping, cache replacement policies- Timers and Counting devices, Techniques for enhancing computational throughput: parallelism and pipelining - Software Development tools-IDE, Incircuit emulator, Target Hardware Debugging.

UNIT II EMBEDDED NETWORKING BY PROCESSORS 9

Embedded Networking: Introduction, I/O Device Ports & Buses- multiple interrupts and interrupt service mechanism – Serial Bus communication protocols -RS232 standard–RS485–USB–Inter Integrated Circuits (I2C)- CAN Bus – Device Drivers -Wireless protocol based on Wifi , Bluetooth, Zigbee –IoT application.

UNIT III RTOS BASED EMBEDDED SYSTEM DESIGN 9

Introduction to basic concepts of RTOS- Synchronising and Scheduling in Uniprocessor and Multiprocessor OS- Task, process & threads, interrupt routines ,Multiprocessing and Multitasking, Preemptive and non-preemptive scheduling, inter task communication- context switching, interrupt latency and deadline, shared memory, message passing-, Interprocess Communication – synchronization between processes-semaphores,Mailbox, pipes, priority inversion, priority inheritance, comparison of Real time Operating systems:VxWorks, OS for mobile applications.

UNIT IV MODELLING WITH HARDWARE/SOFTWARE DESIGN APPROACHES 9

Modelling -embedded hardware and software development approach -Overview of UML modeling with UML, UML Diagrams- Co-Design & CoSynthesis Approaches for System Specification , modeling –Case examples of one DSProcessor, one automated vending machine.

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UNIT V EMBEDDED SYSTEM APPLICATION DEVELOPMENT 9

DSProcessors - Architectural requirement and applications- Computational Features of DSProcessors for signal processing- Shifting , Buffering, IIR/FIR Filtering operation, Addressing Capabilities, Onchip peripherals and Features for External Interfacing& Program Execution–Case example of DSProcessor (TMS320CXX/ TMS320C67xx/ any other)based embedded application using audio, video processing.

TOTAL: 45 PERIODS

NOTE:

Practice through Mini Project/Exercise/Discussions on Design ,Development of embedded Products like : Digital Camera /Adaptive Cruise control in a Car /Mobile Phone / Automated Robonoid /discussions on interface to Sensors, GPS, GSM, Actuators

COURSE OUTCOMES:

At the end of this course, the students will demonstrate the ability

CO1: To understand the functionalities of processor internal blocks, with their requirement.

CO2: Observe that Bus standards are chosen based on interface overheads without sacrificing processor performance

CO3: Understand the role and features of RT operating system, that makes multitask execution possible by processors.

CO4: Understand that using multiple CPU based on either hardcore or softcore helps data overhead management with processing- speed reduction for uC execution.

CO5: Guidelines for consumer product design based on DSP based Embedded processor

REFERENCES:

1. Rajkamal, ‘Embedded system-Architecture, Programming, Design’, TMH,2011.

2. Steven W.Smith,”The Scientist and Engineers Guide for Digital Signal Processing”,Elseiver 2019.

3. Lyla B Das,” Embedded Systems-An Integrated Approach”,Pearson2013

4. Elicia White,”Making Embedded Systems”,O’Reilly Series,SPD,2011

5. Bruce Powel Douglass,”Real-Time UML Workshop for Embedded Systems,Elsevier,2011

6. Advanced Computer architecture , By Rajiv Chopra, S Chand , 2010

7. Jorgen Staunstrup, Wayne Wolf , Hardware / Software Co- Design Principles and Practice, Springer, 2009.

8. Shibu.K.V, “Introduction to Embedded Systems”, TataMcgraw Hill,2009

9. Tammy Noergaard, ”Embedded System Architecture, A comprehensive Guide for Engineers and Programmers”, Elsevier, 2006

10. Peckol, “Embedded system Design”,JohnWiley&Sons,2010

Attested

MAPPING OF COs WITH POs

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

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.

Attested

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**

ET3251 AUTOMOTIVE EMBEDDED SYSTEMS LT P C
3 0 0 3

UNIT I ELECTRONIC ENGINE CONTROL SYSTEMS 9

Overview of Automotive systems, fuel economy, air-fuel ratio, emission limits and vehicle performance; Automotive microcontrollers - Electronic control Unit - Hardware & software selection and requirements for Automotive applications – open source ECU - RTOS - Concept for Engine management-Standards; Introduction to AUTOSAR and Introduction to Society SAE - Functional safety ISO 26262 - Simulation and modeling of automotive system components.

UNIT II SENSORS AND ACTUATORS FOR AUTOMOTIVES 9

Review of sensors- sensors interface to the ECU, conventional sensors and actuators, Modern sensor and actuators - LIDAR sensor- smart sensors- MEMS/NEMS sensors and actuators for automotive applications.

UNIT III VEHICLE MANAGEMENT SYSTEMS 9

Electronic Engine Control - engine mapping, air/fuel ratio spark timing control strategy, fuel control, electronic ignition - Adaptive cruise control - speed control - anti-locking braking system - electronic suspension - electronic steering, Automatic wiper control - body control system; Vehicle system schematic for interfacing with EMS, ECU. Energy Management system for electric vehicles - Battery management system, power management system-electrically assisted power steering system - Adaptive lighting system - Safety and Collision Avoidance.

UNIT IV ONBOARD DIAGONSTICS AND TELEMATICS 9

On board diagnosis of vehicles - System diagnostic standards and regulation requirements Vehicle communication protocols Bluetooth, CAN, LIN, FLEXRAY, MOST, KWP2000 and recent trends in vehicle communications - Navigation - Connected Cars technology - Tracking - Security for data communication - dashboard display and Virtual Instrumentation, multimedia electronics - Role of IOT in Automotive systems

UNIT V ELECTRIC VEHICLES 9

Electric vehicles – Components - Plug in Electrical vehicle - V2G - Charging station – Aggregators - Fuel cells/Solar powered vehicles - Autonomous vehicles.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

CO1: Insight into the significance of the role of embedded system for automotive applications.

CO2: Illustrate the need, selection of sensors and actuators and interfacing with ECU

CO3: Develop the Embedded concepts for vehicle management and control systems.

CO4: Demonstrate the need of Electrical vehicle and able to apply the embedded system technology for various aspects of EVs

CO5: Improved Employability and entrepreneurship capacity due to knowledge up gradation on recent trends in embedded systems design and its application in automotive systems.

REFERENCES:

1. William B. Ribbens, “Understanding Automotive Electronics”, Elseiver,2012
2. Ali Emedi, Mehrdedehsani, John M Miller, “Vehicular Electric power system- land, Sea, Air and Space Vehicles” Marcel Decker, 2004.
3. L.Vlacic, M.Parent, F.Harahima,” Intelligent Vehicle Technologies”, SAE International,2001.
4. Jack Erjavec,JeffArias, “Alternate Fuel Technology-Electric, Hybrid& Fuel Cell Vehicles”, Cengage , 2012.
5. Electronic Engine Control technology - Ronald K Jurgen Chilton’s guide to Fuel Injection - Ford.
6. Automotive Electricals/Electronics System and Components, Tom Denton, 3rd. Edition, 2004.
7. Uwe Kiencke, Lars Nielsen, “Automotive Control Systems: For Engine, Driveline, and Vehicle”, Springer; 1 edition, March 30, 2000.
8. Automotive Electricals Electronics System and Components, Robert Bosch Gmbh, 4th Edition, 2004.
9. Automotive Hand Book, Robert Bosch, Bently Publishers, 1997.
10. Jurgen, R., Automotive Electronics Hand Book.

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MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	-	2	1	1	-	2
CO2	2	3	2	2	2	3
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	2
CO5	3	3	3	3	3	2
Average	**2.75**	**2.8**	**2.4**	**2.4**	**2.75**	**2.2**

ET3057 INFORMATION MODELLING FOR SMART PROCESS **LT P C**
3 0 0 3

UNIT I INTRODUCTION TO IMMERSIVE TECHNOLOGIES 9
Introduction on Virtual reality - Augmented reality - Mixed reality - Extended reality - VR Devices - AR Devices - Applications

UNIT II SOFTWARE TOOLS 9
Intro to Unity - Unity editor workspace - Intro to C# and visual studio - Programming in Unity - Intro to Unreal Engine - UE4 Editor workspace - Intro to Blueprint programming - Programming in

UNIT III BUILDING AR AND VR APPLICATIONS 9
AR SDKs for unity and unreal engine - Working with SDKs for unity - Developing AR application in unity - Building AR application Developing VR application in - Building VR application-

UNIT IV UAE 9
DRONE concept - DESIGN, FABRICATION AND PROGRAMMING - Drone Flying and Operation-Applications of Drone for Electrical Infrastructure Development and Monitoring.

UNIT V CASE STUDIES 9
AR, VR ,ER and MR based Applications development for Industrial Automation .

TOTAL: 45 PERIODS

COURSE OUTCOMES:
At the end of this course, the students will have the ability to
CO1: Able to understand the core concepts and principles behind immersive technologies, such as virtual reality (VR), augmented reality (AR), and mixed reality (MR)
CO2: Able to learn software tools specifically designed for information modeling in the context of smart processes.
CO3: Able to learn the principles and techniques for creating immersive AR/VR experiences, including 3D modeling, interaction design.
CO4: Able to learn about the unique challenges, opportunities, and requirements associated with implementing smart processes in the UAE.
CO5: Able to develop the ability to analyze and evaluate real-world case studies that demonstrate the use of augmented reality (AR), virtual reality (VR), extended reality (ER), and mixed reality (MR) technologies in smart process environments.

Attested

REFERENCES:
1."Smart Process: Designing the Future Enterprise" by Peter Fingar and Harsha Kumar (Published

in 2009)
2. "Information Modeling and Relational Databases: From Conceptual Analysis to Logical Design" by Terry Halpin, Tony Morgan, and Steve Morgan (Published in 2008)
3."Business Process Modeling, Simulation and Design" by Manuel Laguna and Johan Marklund (Published in 2013)
4."Enterprise Architecture at Work: Modelling, Communication, and Analysis" by Marc Lankhorst (Published in 2016)
5."Smart Business Processes: How to Manage the Process Revolution" by Gil Laware and Keith Harrison-Broninski (Published in 2014)

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**

ET3062 MEMS AND NEMS TECHNOLOGY **L T 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.

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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**

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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

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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**

ET3052 BLOCKCHAIN TECHNOLOGIES **L T P C 3 0 0 3**

UNIT I INTRODUCTION OF CRYPTOGRAPHY AND BLOCKCHAIN 9

Introduction to Blockchain, Blockchain Technology Mechanisms & Networks, Blockchain Origins, Objective of Blockchain, Blockchain Challenges, Transactions and Blocks, P2P Systems, Keys as Identity, Digital Signatures, Hashing, and public key cryptosystems, private vs. public Blockchain-Hardware architecture for Blockchain.

UNIT II BITCOIN AND CRYPTOCURRENCY 9

Introduction to Bitcoin, The Bitcoin Network, The Bitcoin Mining Process, Mining Developments, Bitcoin Wallets, Decentralization and Hard Forks, Ethereum Virtual Machine (EVM), Merkle Tree, Double-Spend Problem, Blockchain and Digital Currency, Transactional Blocks, Impact of Blockchain Technology on Cryptocurrency.

UNIT III INTRODUCTION TO ETHEREUM 9

Introduction to Ethereum, Consensus Mechanisms, Metamask Setup, Ethereum ~~Accounts~~, , Transactions, Receiving Ethers, Smart Contracts.

UNIT IV INTRODUCTION TO HYPERLEDGER AND SOLIDITY PROGRAMMING 10

Introduction to Hyperledger, Distributed Ledger Technology & its Challenges, Hyperledger & Distributed Ledger Technology, Hyperledger Fabric, Hyperledger Composer. Solidity - Language of Smart Contracts, Installing Solidity & Ethereum Wallet, Basics of Solidity, Layout of a Solidity Source File & Structure of Smart Contracts, General Value Types.

UNIT V BLOCKCHAIN APPLICATIONS 8

Internet of Things, Medical Record Management System, Domain Name Service and Future of Blockchain, Alt Coins.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

After the completion of this course, student will be able to
CO1: Understand and explore the working of Blockchain technology
CO2: Analyze the working of Smart Contracts
CO3: Understand and analyze the working of Hyperledger
CO4: Apply the learning of solidity to build de-centralized apps on Ethereum
CO5: Develop applications on Blockchain

REFERENCES:

1. Imran Bashir, "Mastering Blockchain: Distributed Ledger Technology, Decentralization, and Smart Contracts Explained", Second Edition, Packt Publishing, 2018.
2. Narayanan, J. Bonneau, E. Felten, A. Miller, S. Goldfeder, "Bitcoin and Cryptocurrency Technologies: A Comprehensive Introduction" Princeton University Press, 2016
3. Antonopoulos, Mastering Bitcoin, O'Reilly Publishing, 2014. .
4. Antonopoulos and G. Wood, "Mastering Ethereum: Building Smart Contracts and Dapps", O'Reilly Publishing, 2018.
5. D. Drescher, Blockchain Basics. Apress, 2017.

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	-	-	-
Average	**1**	**-**	**2**	**2**	**1.5**	**-**

Attested

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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

MapReduce - 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**	**-**

ET3055 EMBEDDED NETWORKING AND AUTOMATION OF ELECTRICAL SYSTEM **LT P C 3 0 0 3**

UNIT I BUILDING SYSTEM AUTOMATION 9

Sensor Types & Characteristics: Sensing Voltage, Current, flux, Torque, Position, Proximity, Accelerometer - Data acquisition system - Signal conditioning circuit design - Uc Based & PC based data acquisition - uC for automation and protection of electrical appliances -processor based digital controllers for switching Actuators: Stepper motors, Relays -System automation with multi-channel Instrumentation and interface .

UNIT II EMBEDDED NETWORKING OF INSTRUMENT CLUSTER 9

Embedded Networking: Introduction - Cluster of Instruments in System - Comparison of bus protocols - RS 232C - embedded ethernet - MOD bus and CAN bus, LIN BUS - Introduction to WSN - Commercially available sensor nodes - Zigbee protocol - Network Topology Energy efficient MAC protocols - SMAC - Data Centric routing Applications of sensor networks - Database perspective on sensor networks - IoT Applications.

UNIT III AUTOMATION OF SUBSTATION 9

Substation automation - Distribution SCADA system principles - role of PMU, RTU, IEDs, BUS for smart Substation automation- Introduction to Role of IEC 61850, IEEEC37.118 std- Interoperability and IEC 61850 - challenges of Substations in Smart Grid - challenges of Energy Storage and Distribution Systems monitoring - Communication Challenges in monitoring electric utility asset.

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UNIT IV METERING OF SMART GRID 9

Characteristics of Smart Grid - Generation by Renewable Energy Sources based on solar grid - Challenges in Smart Grid and Microgrids - electrical measurements with AMI - Smart meters for EV plug in electric vehicles power management - Home Area Net metering and Demand side Energy Management applications.

UNIT V SMART METERS FOR PQ MONITORING 9

Power Quality issues of Grid connected Renewable Energy Sources -Smart meters for Power Quality monitoring and Control - Power Quality issues -Surges - Flicker - Interharmonics - Transients - Power Quality Benchmarking - Power Quality Meters- Meter data management In Smart Grid-, communication enabled Power Quality metering

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

CO1: Demonstrate criteria of choice of sensors, components to build meters.

CO2: Illustrate the demand for BUS communication protocols are introduced

CO3: Analyse the need and standards in Substation automation

CO4: Deployment of PAN for metering networked commercial applications

CO5: Improved Employability and entrepreneurship capacity due to knowledge up gradation on recent trends in embedded networked communications.

REFERRENCES:

1. Control and automation of electrical power distribution systems, James Northcote-Green, Robert Wilson, CRC, Taylor and Francis, 2006
2. Krzysztof Iniewski," Smart Grid, Infrastructure& Networking", TMcGH,2012
3. Robert Faludi," Building Wireless Sensor Networks,O'Reilly,2011
4. Mohammad Ilyas And Imad Mahgoub, 'Handbook of sensor Networks: Compact wireless and wired sensing systems', CRC Press,2005
5. Shih-Lin Wu,Yu-Chee Tseng,{"Wireless Ad Hoc Networking, PAN, LAN, SAN, Aurebach Pub,2012
6. Sanjay Gupta, "Virtual Instrumentation, LABVIEW", TMH, New Delhi, 2003
7. Ernest O. Doeblin and Dhanesh N Manik, "Measurement Systems - Application and Design", 5th Edn, TMH, 2007.
8. Bhaskar Krishnamachari, 'Networking wireless sensors', Cambridge press 2005

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	1	2	1
CO2	1	-	2	2	3	1
CO3	3	1	2	-	-	-
CO4	2	-	2	3	3	2
CO5	2	1	2	-	-	3
Average	**2.2**	**1**	**2**	**2**	**2.66**	**1.75**

Attested

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ET3066 **SMART SYSTEM DESIGN** **LT P C**
3 0 0 3

UNIT I SYSTEM DESIGN OVERVIEW 9

Overview of a smart system - Design Requirements - Hardware and software selection & co-design - Smart sensors and Actuators - Communication protocols used in smart systems - Data Analytics: Need & Types - Open-source Analytics Platform for embedded systems (IFTTT &Thingspeak) - Smart Microcontrollers - Embedded system for Smart card design and development - Recent trends.

UNIT II HOME AUTOMATION 9

Home Automation - Design Considerations: Control Unit, Sensing Requirements, Communication, Data Security - System Architecture - Essential Components - Linux and Raspberry Pi - Design and Real-Time implementation.

UNIT III SMART APPLIANCES AND ENERGY MANAGEMENT 9

Energy Management: Demand-side Load Management: Energy scheduling - Significance of smart appliances in energy management - Embedded and Integrated Platforms for Energy Management - Smart Meters: Significance, Architecture & Energy Measurement Technique - Smart Networks for Embedded Appliances - Security Considerations.

UNIT IV SMART WEARABLE DEVICES 9

Application of Smart Wearables in Healthcare & Activity Monitoring - Functional requirements- Selection of body sensors, Hardware platform, OS and Software platform - Selection of suitable communication protocol. Case Study: Design of a wearable, collecting heart-beat, temperature and monitoring health status using a smartphone application.

UNIT V EMBEDDED SYSTEMS AND ROBOTICS 9

Robots and Controllers components - Aerial Robotics - Mobile Robot Design - Three-Servo Ant Robot - Autonomous Hex copter System.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

CO1: Understand the concepts of smart system design and its present developments.

CO2: Illustrate different embedded open-source and cost-effective techniques for developing solution for real time applications.

CO3: Acquire knowledge on different platforms and Infrastructure for Smart system design.

CO4: Infer about smart appliances and energy management concepts.

CO5: Apply and improve Employability and entrepreneurship capacity due to knowledge upgradation on embedded system technologies.

REFERENCES:

1. Thomas Bräunl, Embedded Robotics, Springer, 2003.
2. Grimm, Christoph, Neumann, Peter, Mahlknech and Stefan, Embedded Systems for Smart Appliances and Energy Management, Springer 2013.
3. Raj Kamal, Embedded Systems - Architecture, Programming and Design, McGraw- Hill, 2008
4. NilanjanDey, Amartya Mukherjee, Embedded Systems and Robotics with Open-Source Tools, CRC press, 2016.
5. Karim Yaghmour, Embedded Android, O'Reilly, 2013.
6. Steven Goodwin, Smart Home Automation with Linux and Raspberry Pi, Apress, 2013
7. C.K.Toh, AdHoc mobile wireless networks, Prentice Hall, Inc, 2002.
8. KazemSohraby, Daniel Minoli and TaiebZnati, Wireless Sensor Networks Technology,Protocols, and Applications, John Wiley & Sons, 2007.

9. Anna Ha´c, Wireless Sensor Network Designs, John Wiley & Sons Ltd, 2003.
10. Robert Faludi, Wireless Sensor Networks, O'Reilly, 2011.

MAPPING OF COs WITH POs

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

ET3064 RECONFIGURABLE PROCESSOR AND SoC DESIGN **LT P C**
3 0 0 3

UNIT I RECONFIGURABLE PROCESSORS **9**
Introduction to reconfigurable processor - Reconfigurable Computing - Programming elements and Programming Tools for Reconfigurable Processors, ASIC design flow - Hardware/Software Co-design - FPAA Architecture overview - recent trends in Reconfigurable Processor & SoC.

UNIT II FPGA TECHNOLOGIES **9**
FPGA Programming technology - Alternative FPGA architectures: MUX Vs LUT based logic blocks - CLB Vs LAB Vs Slices - Fast carry chains - Embedded RAMs - Routing for FPGAs - Circuits and Architectures for Low-Power FPGAs - Physical Design.

UNIT III FPGA ARCHITECTURE **9**
Challenges in FPGA processor design-Opportunities of FPGA processor design- Designing Soft-core Processors - Designing Hardcore Processors -hardware/software co design and co-simulation- FPGA to multi core embedded computing - FPGA based on-board computer system.

UNIT IV RECONFIGURABLE SOC PROCESSORS **9**
SoC Overview -Architecture and applications of Virtex II pro, Zynq-7000, Excalibur, Cyclone V - A7, E5- FPSLIC- Multicore SoCs.

UNIT V RECONFIGURABLE PROCESSOR AND SOC APPLICATIONS **9**
Reconfigurable processor-based DC motor control - digital filter design - mobile phone development - High Speed Data Acquisition - Image Processing application - controller implementation for mobile robot- Crypto-processor.

TOTAL: 45 PERIODS

COURSE OUTCOMES:
At the end of this course, the students will have the ability to
CO1: Illustrate the need of reconfigurable computing and hardware-software co design
CO2: Demonstrate the significance of FPGA technology
CO3: Apply the concept of FPGA technology and understand FPGA architectures.
CO4: Interpret the operation of SoC processor.
CO5: Relate and improve Employability and entrepreneurship capacity due to knowledge up-gradation on reconfigurable computing and SoC design.

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REFERENCES:

1. Nurmi, Jari (Ed.) "Processor Design System-On-Chip Computing for ASICs and FPGAs" Springer, 2007.
2. Ian Grout, "Digital system design with FPGAs and CPLDs" Elsevier, 2008
   Joao Cardoso, Michael Hübner, "Reconfigurable Computing: From FPGAs to Hardware/Software Codesign" Springer, 2011.
3. Ron Sass and AnderewG.Schmidt, "Embedded System design with platform FPGAs: Principles and Practices", Elsevier, 2010.
4. Steve Kilts, "Advanced FPGA Design: Architecture, Implementation, and Optimization" Willey, 2007
5. Pierre-Emmanuel Gaillardon, Reconfigurable Logic: Architecture, Tools, and Applications, 1st Edition, CRC Press, 2015.

MAPPING OF COs WITH POs

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	-	-	-	-	-	-
CO2	-	2	3	-	-	-
CO3	-	-	2	1	2	-
CO4	-	1	3	-	-	-
CO5	-	-	-	-	-	3
Average	**-**	**1.5**	**2.66**	**1**	**2**	**3**

ET3056 ENTREPRENEURSHIP AND EMBEDDED PRODUCT DEVELOPMENT LT P C
3 0 0 3

UNIT I INTRODUCTION TO ENTREPRENEURSHIP 9

Entrepreneurial culture and structure - theories of entrepreneurship - entrepreneurial motivation - establishing entrepreneurial systems - financial information and intelligence, rewards and motivation - concept bank - Role of industrial Fairs - Design thinking – IPR- Patent- challenges in entrepreneurship.

UNIT II RESPONSIBILITIES IN ENTREPRENEURSHIP 9

Steps for starting a small industry - selection of type of organization -Incentives and subsidies - Central Govt. schemes and State Govt. Schemes - incentives to SSI -registration, Registration and Licensing requirements for sales tax, CST, Excise Duty - Power - Exploring export possibilities - incentives for exports - import of capital goods and raw materials - Entrepreneurship development programmes in India- Role and Improvement in Indian Economy.

UNIT III CONCEPTS OF PRODUCT DEVELOPMENT 9

Generic product Development Phases - Product Development Process Flows - Basics of Concept Generation - Five Step Method - Creative thinking methods and problem solving - design concepts - Product Architecture - component standardization - Bill of materials-Product development management - Portfolio Architecture – Benchmarking.

UNIT IV APPROACHES FOR NEW PRODUCT DEVELOPMENT 9

Idea Generation - Industrial Design - Brainstorming Methods - SWOT Analysis-Concept Development & Testing - Risk Management Process - Critical Path Analysis & PERT - Reverse Engineering Methodology - need for Involving CAE, CAD, CAM tools - Prototype basics - Rapid Prototyping -

Prototyping Techniques - Planning for prototypes - Economic & Cost Analysis

UNIT V ENTREPRENEURSHIP IN EMBEDDED SYSTEM 9

Entrepreneurship opportunities in Embedded system technologies – Design thinking -Embedded system Product development - Entrepreneurial skills for embedded system hardware and software architecture, software and hardware co-design and challenges; problems of entrepreneurship in Embedded system field - case studies: Mobile phone development - automation components - Washing machine - Food Processing system and devices- High Performance embedded computers - Industrial Controllers

TOTAL : 45 PERIODS

COURSE OUTCOMES:

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

CO1: Analyze the internal/external factors affecting a business/organization to evaluate business opportunities.

CO2: Demonstrate extemporaneous speaking skills developed through in-class discussion of text materials, case study analyses, and current entrepreneurship-related issues.

CO3: Apply and Relate Key concepts underpinning entrepreneurship and its application in the recognition and exploitation of product/ service/ process opportunities.

CO4: Interpret various aspects of design such as industrial design, design of Consumer specific product, its Reverse Engineering manufacture, economic analysis.

CO5: Improved Employability and entrepreneurship capacity due to knowledge up gradation on recent trends in embedded systems design.

REFERENCES

1 Kuratko, Enmterpreneurship: A Contemporary Approach, Thomson Learning, 2001.
2 Thomas Zimmerer et.al., Essentials of Entrepreneurship and small business Management 3rd Ed. Pearson Education, 2002.
3 Greene, Entrepreneurship: Ideas in Action, Thomson Learning, Mumbai, 2000
4 Jeffry Timmons, New Venture creation, McGraw Hill, 1999.
5 Gupta and Smivasan, Entrepreneurial Development, New Delhi, Sultan Chand, 1992
6 James K.peckol ," Embedded Systems: A contemporary Design Tool", Wiley,2014.
7 Anita Goyal, Karl T Ulrich, Steven D Eppinger, "Product Design and Development ", 4th Edition,2009, Tata McGraw-Hill Education, ISBN-10-007-14679-9
8 George E.Dieter, Linda C.Schmidt, "Engineering Design", McGraw-Hill International Edition,4th Edition, 2009, ISBN 978-007-127189-9

MAPPING OF COs WITH POs

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

Attested

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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**	

MA3161 STATISTICAL METHODS FOR ENGINEERS **LT P C**
4 0 0 4

UNIT I ESTIMATION THEORY **12**

Estimators: Unbiasedness, Consistency, Efficiency and Sufficiency–Maximum Likelihood Estimation – Method of moments.

UNIT II TESTING OF HYPOTHESIS **12**

Tests based on Normal, *t*, χ^2 and *F* distributions for testing of means, variance and proportions – Analysis of *r x c* tables – Goodness of fit.

UNIT III CORRELATION AND REGRESSION **12**

Multiple and Partial Correlation - Method of Least Squares- Plane of Regression - Properties of Residuals - Coefficient of Multiple Correlation - Coefficient of Partial Correlation - Multiple Correlation with total and partial correlations - Regression and Partial correlations in terms of lower order coefficients.

UNIT IV DESIGN OF EXPERIMENTS **12**

Analysis of variance – One-way and two-way classifications – Completely randomized design – Randomized block design – Latin square design.

UNIT V MULTIVARIATE ANALYSIS **12**

Random vectors and Matrices – Mean vectors and Covariance matrices – Multivariate Normal density and its properties – Principal components: Population principal components – Principal components from standardized variables.

TOTAL: 60 PERIODS

OUTCOMES:

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

CO1 Obtain the value of the point estimators using the method of moments and method of maximum Likelihood.

CO2 Use various test statistics in hypothesis testing for mean and variances of large and small samples.

CO3 Determine the regression line using the method of least square and also to calculate the partial and multiple correlation coefficient for the given set of data points.

CO4 Test the hypothesis for several means using one way, two way or three way classifications.

CO5 Get exposure to the principal component analysis of random vectors and matrices.

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REFERENCES:

1. Devore, J.L., "Probability and Statistics for Engineering and the Sciences", Thomson and Duxbury, Singapore, 6th Edition, Boston, 2004.
2. Gupta, S.C., and Kapoor, V.K., "Fundamentals of Mathematical Statistics", Sultan Chand and Sons, Eleventh Edition, Reprint, New Delhi, 2019.
3. Johnson, R. A. and Gupta, C. B., "Miller & Freund's Probability and Statistics for Engineers", Pearson Education, Asia, Eighth Edition, New Delhi, 2015.
4. Johnson, R.A., and Wichern, D.W., "Applied Multivariate Statistical Analysis", Pearson Education, Sixth Edition, New Delhi, 2013.
5. Spiegel, M.R. and Stephens, L.J.," Schaum's outlines on Statistics", Tata McGraw-Hill, 6th Edition, New York, 2018.

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**

MA3155 **ADVANCED NUMERICAL METHODS** **LT P C**
4 0 0 4

UNIT I ALGEBRAIC EQUATIONS 12

Systems of linear equations: Gauss Elimination method, pivoting techniques, Thomas algorithm for tridiagonal system – Jacobi, Gauss Seidel, SOR iteration methods - Systems of nonlinear equations: Fixed point iterations, Newton Method, Eigenvalue problems: power method, Faddeev – Leverrier Method.

UNIT II ORDINARY DIFFERENTIAL EQUATIONS 12

Runge Kutta Methods for system of IVPs, numerical stability, Adams-Bashforth multistep method, solution of stiff ODEs, shooting method, BVP: Finite difference method, collocation method, orthogonal collocation method, Galerkin finite element method.

UNIT III FINITE DIFFERENCE METHOD FOR TIME DEPENDENT PARTIAL DIFFERENTIAL EQUATION 12

Parabolic equations: explicit and implicit finite difference methods, weighted average approximation - Dirichlet and Neumann conditions – Two dimensional parabolic equations – ADI method; First order hyperbolic equations – method of characteristics, Lax - Wendroff explicit and implicit methods; numerical stability analysis, method of lines – Wave equation: Explicit scheme-Stability of above schemes.

UNIT IV FINITE DIFFERENCE METHODS FOR ELLIPTIC EQUATIONS 12

Laplace and Poisson's equations in a rectangular region: Five point finite difference schemes, Leibmann's iterative methods, Dirichlet and Neumann conditions – Laplace equation in polar coordinates: finite difference schemes – approximation of derivatives near a curved boundary while using a square mesh.

UNIT V FINITE ELEMENT METHOD 12

Partial differential equations – Finite element method - collocation method, orthogonal collocation method, Galerkin finite element method.

TOTAL: 60 PERIODS

OUTCOMES:

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

CO1 Get familiarized with the methods which are required for solving system of linear, nonlinear equations and eigenvalue problems.
CO2 Solve the BVPs and the system of IVPs by appropriate methods discussed.
CO3 Solve time dependent parabolic PDEs by using various methodologies up to dimension two.
CO4 Solve elliptic equations by finite difference methods.
CO5 Use the ideas of solving PDEs by finite element method.

REFERENCES:

1. Burden, R.L., and Faires, J.D., "Numerical Analysis – Theory and Applications", Cengage Learning, India Edition, New Delhi, 2010.
2. Gupta S.K., "Numerical Methods for Engineers", New Age Publishers, 3rd Edition, New Delhi, 2015.
3. Jain M. K., Iyengar S. R. K., Jain R.K., "Computational Methods for Partial Differential Equations", New Age Publishers, 2nd Edition, New Delhi, 2016.
4. Morton K.W. and Mayers D.F., "Numerical solution of partial differential equations", Cambridge University press, Cambridge, 2005.
5. Sastry S.S., "Introductory Methods of Numerical Analysis", Prentice - Hall of India Pvt. Limited, 5th Edition, New Delhi, 2012.

6. Saumyen Guha and Rajesh Srivastava, “Numerical methods for Engineering and Science”, Oxford Higher Education, New Delhi, 2010.

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**

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

CO1 Apply the concepts of Matrix theory in Electrical Engineering problems.

CO2 Use calculus of variation techniques to solve various engineering problems.

CO3 Solve electrical engineering problems involving one-dimensional random variables.

CO4 Formulate and solve linear programming problems in electrical engineering.

CO5 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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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**

Attested

DIRECTOR
Centre for Academic Courses
Anna University, Chennai-600 025

MA3160 PROBABILITY AND STATISTICAL METHODS L T P C
4 0 0 4

UNIT I 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 – Functions of a Random Variable.

UNIT II TWO DIMENSIONAL RANDOM VARIABLES 12

Joint distributions – Marginal and Conditional distributions – Functions of two dimensional random variables – Regression Curve – Correlation.

UNIT III ESTIMATION THEORY 12

Unbiased Estimators – Method of Moments – Maximum Likelihood Estimation - Curve fitting by Principle of least squares – Regression Lines.

UNIT IV TESTING OF HYPOTHESES 12

Sampling distributions - Type I and Type II errors - Tests based on Normal, t, Chi-Square and F distributions for testing of mean, variance and proportions – Tests for Independence of attributes and Goodness of fit.

UNIT V MULTIVARIATE ANALYSIS 12

Random Vectors and Matrices - Mean vectors and Covariance matrices - Multivariate Normal density and its properties - Principal components: Population principal components – Principal components from standardized variables.

TOTAL: 60 PERIODS

OUTCOMES:

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

CO1 Use the appropriate and relevant, fundamental and applied mathematical and statistics knowledge and methodologies in solving practical problem.

CO2 Bring together and flexibly apply knowledge to characterize, analyse and solve a wide range of problems.

CO3 Understand the balance between the complexity/accuracy of the mathematical/statistical models used and the timeliness of the delivery of the solution.

CO4 Steeped in research methods and rigor.

CO5 Develop critical thinking based on empirical evidence and the scientific approach to knowledge development.

REFERENCES:

1. Dallas E Johnson , “Applied multivariate methods for data analysis”, Thomson and Duxbury press, Singapore, 1998.
2. Gupta S.C. and Kapoor V.K. “Fundamentals of Mathematical Statistics”, Sultan and Sons, 11th Edition, Reprint, New Delhi, 2019.
3. Jay L. Devore, “Probability and statistics for Engineering and Sciences”, Thomson and Duxbury, 9th Edition, Singapore, Boston, 2016.
4. Krishnaiah K. and Shahabudeen P, “Applied Design of Experiments and Taguchi Methods”, PHI, New Delhi, 2012.
5. Richard A. Johnson and Dean W. Wichern, “Applied Multivariate Statistical Analysis”, Pearson Education, Fifth Edition, 6th Edition, New Delhi, 2013.
6. Richard Johnson. ”Miller & Freund‟s Probability and Statistics for Engineer”, Prentice Hall of India Private Ltd., 8th Edition, New Delhi, 2011.

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**