DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

ANNA UNIVERSITY, CHENNAI – 25

VISION OF THE DEPARTMENT

The vision of Anna University is to be a world class institution by producing professionals with high technical knowledge, professional skills and ethical values, and remain as a preferred partner to the industry and community for their economic and social development through excellence in teaching, research and consultancy. Anna University shall be recognized as a point of reference, a catalyst, a facilitator, a trend setter and a leader in technical education.

MISSION OF THE DEPARTMENT

To produce full fledged Electrical and Electronics Engineers to cater to the needs of the modern industries and be useful for building the nation.

ANNA UNIVERSITY, CHENNAI
UNIVERSITY DEPARTMENTS
REGULATIONS - 2019
CHOICE BASED CREDIT SYSTEM
M.E. POWER SYSTEMS ENGINEERING

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs) :

I. To prepare the students for successful career in electrical power industry, research and teaching institutions.
II. To provide strong foundation in Power Engineering, necessary for day-to-day operation and planning of Power System.
III. To develop the ability to assess the state of the system using Wide Area Measurements.
IV. To develop the ability to design damping controllers to enhance the stability margin and power transfer capability of the Power System.
V. To provide strong foundation in the power system protection and relaying.
VI. To promote student awareness for the lifelong learning and introduce them to the professional ethics

PROGRAMME OUTCOMES (POs):

2. PROGRAMME OUTCOMES (POs):

PO	Graduate Attribute	Programme Outcome
1.	Engineering Knowledge	Apply knowledge of basic science and engineering in analysis and modeling of the power system components
2.	Problem Analysis	Formulate, simulate and analyze thePower system under steady state and dynamic conditions
3.	Design / Development of Solutions	Design of Power System protection schemes and damping Controllers to enhance the reliability and stability of the Power System
4.	Conduct investigations of complex problems	Identification of problems such as power swing, sub synchronous resonance and controller interactions, reach of the protective relay, grid integration issues of renewable energy sources
5.	Model tool usage	Model and analyze the Power System under steady state and dynamic conditions using application software packages.
6.	The Engineer and Society	To cater the need for restructuring the grid and incorporation of smartness in grid management
7	Environment and Sustainability	To address various renewable energy sources penetration issues
8.	Ethics	To impart Ethics in ensuring grid security in professional manner
9.	Individual and team work	Function in a multi-disciplinary team
10.	Communication	Proficiency in oral and writtenCommunication to present technical subjects
11.	Project Management and Finance	Implement cost effective and cutting edge technologies in Power System
12.	Life-long learning	Continue professional development and learning as a life-long activity.

PROGRAM SPECIFIC OUTCOMES (PSOs):

By the completion of M.E.Power System Engineering program the student will have following Program Specific Outcomes.

1. Ability to apply knowledge of electrical power system principles and techniques for power system applications.
2. Ability to develop steady-state and dynamic models of various power system components to perform system studies for generation and transmission system expansion planning.
3. Ability to design and develop various indigenous controllers for efficient and economic operation of power system.
4. Ability to design and develop principles, practices and state-of-art techniques to protect the power system.
5. Ability to analyze various electricity market models with distributed energy resources and demand response management.
6. Ability to incorporate interdisciplinary knowledge to address the recent problems in the electrical power industry.

PEO / PO Mapping:

Programme Educational Objectives	Programme Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
I	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	✓				✓				✓	✓	✓	
III					✓		✓					
IV		✓	✓	✓		✓			✓			
V	✓			✓	✓		✓		✓	✓	✓	
VI	✓		✓	✓		✓		✓	✓			✓

Mapping of Course Outcome and Program Outcomes

		Course Name	PO 01	PO 02	PO 03	PO 04	PO 05	PO 06	PO 07	PO 08	PO 09	PO 10	PO 11	PO 12
YEAR 1	Semester1	Power System Analysis	✓	✓										
		Analysis and computation of Electromagnetic Transients in Power Systems	✓	✓	✓	✓								
		Power System Dynamics	✓	✓	✓	✓								
		Program Elective I												
		Research Methodology and IPR												
		Audit Course I												
		Power System Simulation Lab		✓	✓		✓	✓		✓	✓			
		Renewable Energy Lab					✓	✓	✓	✓	✓			
	Semester2	Advanced Power system Protection	✓	✓		✓				✓				
		HVDC and FACTS				✓	✓							
		Restructured Power System			✓	✓			✓	✓				
		Program Elective II												
		Program Elective III												
		Audit Course II												
		Power System Protection Lab		✓	✓		✓	✓		✓	✓			
		Power Converters Lab					✓	✓			✓	✓	✓	
		Mini Project					✓	✓			✓	✓	✓	
YEAR 2	Semester3	Program Elective IV												
		Program Elective V												
		Open Elective (one from the list of 6 Open Electives)												
		Project Phase I					✓	✓			✓	✓		✓
	Semester 4	Project Phase II					✓	✓			✓	✓		✓

ANNA UNIVERSITY, CHENNAI
UNIVERSITY DEPARTMENTS
REGULATIONS - 2019
CHOICE BASED CREDIT SYSTEM
M.E. POWER SYSTEMS ENGINEERING (FULL TIME)
CURRICULUM AND SYLLABUS I TO IV SEMESTERS

SEMESTER I

S. NO.	COURSE CODE	COURSETITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	PS5101	Power System Analysis	PCC	3	1	0	4	4
2.	PS5151	Analysis and Computation of Electromagnetic Transients in Power Systems	PCC	3	1	0	4	4
3.	PS5102	Power System Dynamics	PCC	3	1	0	4	4
4.		Program Elective I	PEC	3	0	0	3	3
5.	RM5151	Research Methodology and IPR	RMC	2	0	0	2	2
6.		Audit Course I*		2	0	0	2	0
PRACTICALS								
7.	PS5111	Power System Simulation Laboratory	PCC	0	0	4	4	2
8.	PW5261	Renewable Energy Laboratory	PCC	0	0	4	4	2
			TOTAL	**16**	**3**	**8**	**27**	**21**

*Audit Course is optional

SEMESTER II

S. NO.	COURSE CODE	COURSETITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	PS5201	Advanced Power System Protection	PCC	3	0	0	3	3
2.	PS5251	HVDC and FACTS	PCC	3	1	0	4	4
3.	PS5252	Restructured Power System	PCC	3	0	0	3	3
4.		Program Elective II	PEC	3	0	0	3	3
5.		Program Elective III	PEC	3	0	0	3	3
6.		Audit Course II*		2	0	0	2	0
PRACTICALS								
7.	PS5211	Power System Protection Laboratory	PCC	0	0	4	4	2
8.	PE5161	Power Converters Laboratory	PCC	0	0	4	4	2
9.	PS5212	Mini Project	EEC	0	0	4	4	2
			TOTAL	**17**	**1**	**12**	**30**	**22**

*Audit Course is optional

SEMESTER III

S. NO.	COURSE CODE	COURSETITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.		Program Elective IV	PEC	3	0	0	3	3
2.		Program Elective V	PEC	3	0	0	3	3
3.		Open Elective (one from list of 6 courses)	OEC	3	0	0	3	3
PRACTICALS								
4.	PS5311	Project Phase I	EEC	0	0	12	12	6
5.								
			TOTAL	**9**	**0**	**12**	**21**	**15**

SEMESTER IV

S. NO.	COURSE CODE	COURSETITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICALS								
1.	PS5411	Project Phase II	EEC	0	0	24	24	12
			TOTAL	**0**	**0**	**24**	**24**	**12**

TOTAL NO OF CREDITS:70

ANNA UNIVERSITY, CHENNAI
UNIVERSITY DEPARTMENTS
REGULATIONS - 2019
CHOICE BASED CREDIT SYSTEM
M.E. POWER SYSTEMS ENGINEERING (PART TIME)
CURRICULUM AND SYLLABUS I TO VI SEMESTERS

SEMESTER I

S. NO.	COURSE CODE	COURSETITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	PS5101	Power System Analysis	PCC	3	1	0	4	4
2.	PS5151	Analysis and Computation of Electromagnetic Transients in Power Systems	PCC	3	1	0	4	4
3.		Audit Course I*		2	0	0	2	0
PRACTICALS								
4.	PS5111	Power System Simulation Lab	PCC	0	0	4	4	2
			TOTAL	**8**	**2**	**4**	**14**	**10**

*Audit Course is optional

SEMESTER II

S. NO.	COURSE CODE	COURSETITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	PS5201	Advanced Power System Protection	PCC	3	0	0	3	3
2.	PS5252	Restructured Power System	PCC	3	0	0	3	3
3.		Audit Course II*		2	0	0	2	0
PRACTICALS								
4.	PS5211	Power System Protection Lab	PCC	0	0	4	4	2
			TOTAL	**8**	**0**	**4**	**12**	**8**

*Audit Course is optional

SEMESTER III

S. NO.	COURSE CODE	COURSETITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	PS5102	Power System Dynamics	PCC	3	1	0	4	4
2.		Program Elective I	PEC	3	0	0	3	3
3.	RM5151	Research methodology and IPR	RMC	2	0	0	2	2
PRACTICALS								
4.	PW5261	Renewable Energy Lab	PCC	0	0	4	4	2
			TOTAL	**8**	**1**	**4**	**13**	**11**

SEMESTER IV

S. NO.	COURSE CODE	COURSETITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	PS5251	HVDC and FACTS	PCC	3	1	0	4	4
2.		Program Elective II	PEC	3	0	0	3	3
3.		Program Elective III	PEC	3	0	0	3	3
PRACTICALS								
4.	PE5161	Power Converters Lab	PCC	0	0	4	4	2
5.	PS5212	Mini Project	EEC	0	0	4	4	2
			TOTAL	**9**	**1**	**8**	**18**	**14**

SEMESTER V

S. NO.	COURSE CODE	COURSETITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.		Program Elective IV	PEC	3	0	0	3	3
2.		Program Elective V	PEC	3	0	0	3	3
3.		Open Elective (one from list of 6 courses)	OEC	3	0	0	3	3
PRACTICALS								
4.	PS5311	Project Phase I	EEC	0	0	12	12	6
5.								
			TOTAL	**9**	**0**	**12**	**21**	**15**

SEMESTER VI

S. NO.	COURSE CODE	COURSETITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICALS								
1.	PS5411	Project Phase II	EEC	0	0	24	24	12
			TOTAL	**0**	**0**	**24**	**24**	**12**

TOTAL NO OF CREDITS:70

PROGRAM CORE COURSES (PCC)

Sl.No	COURSE CODE	Course Title	Periods per week			Credits	Semester
			Lecture	Tutorial	Practical		
1	PS5101	Power System Analysis	3	1	0	4	1
2	PS5151	Analysis and Computation of Electromagnetic Transients in Power Systems	3	1	0	4	1
3	PS5102	Power System Dynamics	3	1	0	4	1
4	PS5111	Power System Simulation lab	0	0	4	2	1
	PW5261	Renewable Energy lab	0	0	4	2	1
5	PS5201	Advanced Power System Protection	3	0	0	3	2
6	PS5251	HVDC and FACTS	3	1	0	4	2
7	PS5252	Restructured Power System	3	0	0	3	2
8	PS5211	Power System Protection lab	0	0	4	2	2
9	PE5161	Power Converters Lab	0	0	4	2	2
					Total Credits	30	

PROGRAM ELECTIVE COURSES [PEC]

Si.no	COURSE CODE	Course title	Periods per week			Contact Periods	Credits
			L	T	P		
1.	PS5001	Power System Planning and Reliability	3	0	0	3	3
2.	PS5002	Industrial Power System Analysis and Design	3	0	0	3	3
3.	PS5003	Advanced Power System Dynamics	3	0	0	3	3
4.	PS5004	Power System State Estimation	3	0	0	3	3
5.	PS5071	Application of AI Techniques to Power Systems	3	0	0	3	3
6.	PS5072	Application of DSP to Power System Protection	3	0	0	3	3
7.	PS5073	Distributed Generation Control and Automation	3	0	0	3	3

8.	PS5074	Optimization Techniques	3	0	0	3	3
9.	PS5075	Smart Grid	3	0	0	3	3
10.	PS5076	Wind Energy Conversion System	3	0	0	3	3
11.	HV5075	Principles of Electric Power Transmission	3	0	0	3	3
12.	HV5073	Electromagnetic Interference and Compatibility	3	0	0	3	3
13.	HV5072	Design of Substations	3	0	0	3	3
14.	CO5071	Advanced Non-linear Control	3	0	0	3	3
15.	CO5251	Machine Learning	3	1	0	4	4
16.	CO5075	System Theory	3	0	0	3	3
17.	CO5151	Control System Design	4	0	0	4	4
18.	CO5073	Optimal Control and Filtering	3	0	0	3	3
19.	CO5074	System Identification and Adaptive Control	3	0	0	3	3
20.	PE5153	Modelling and Design of SMPS	3	0	0	3	3
21.	PE5252	Vector Control of AC Machines	3	1	0	4	4
22.	PE5074	Power Quality	3	0	0	3	3
23.	PE5072	Advanced Power Converters	3	0	0	3	3
24.	PE5152	Analysis of Power Converters	3	1	0	4	4
25.	PE5151	Analysis of Electrical Machines	3	1	0	4	4
26.	PE5073	Power Electronics for Renewable Energy Systems	3	0	0	3	3
27.	PW5071	Electric Vehicles and Power Management	3	0	0	3	3
28.	PW5074	Energy Storage Technologies	3	0	0	3	3
29.	PW5075	Grid Integration of Renewable Energy Sources	3	0	0	3	3
30.	PW5076	Micro-grid Operation and Control	3	0	0	3	3
31.	PW5077	Renewable Energy Technology	3	0	0	3	3
32.	PW5078	SCADA System and Applications Management	3	0	0	3	3
33.	ET5071	Advanced Digital Signal Processing	3	0	0	3	3

RESEARCH METHODOLOGY AND IPR COURSES (RMC)

Sl.No	COURSE CODE	Course Title	Periods per week			Credits	Semester
			Lecture	Tutorial	Practical		
1.	RM5151	Research Methodology and IPR	2	0	0	2	1
					Total Credits	**2**	

OPEN ELECTIVE COURSES [OEC]

*(Out of 6 Courses one Course must be selected)

S.NO	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			Lecture	Tutorial	Practical		
1.	OE5091	Business Data Analytics	3	0	0	3	3
2.	OE5092	Industrial Safety	3	0	0	3	3
3.	OE5093	Operations Research	3	0	0	3	3
4.	OE5094	Cost Management of Engineering Projects	3	0	0	3	3
5.	OE5095	Composite Materials	3	0	0	3	3
6.	OE5096	Waste to Energy	3	0	0	3	3

AUDIT COURSES (AC)

Registration for any of these courses is optional to students

SL. NO	COURSE CODE	COURSETITLE	PERIODSPERWEEK			CREDITS	SEMESTER
			Lecture	Tutorial	Practical		
1.	AX5091	English for Research Paper Writing	2	0	0	0	1/2
2.	AX5092	Disaster Management	2	0	0	0	
3.	AX5093	Sanskrit for Technical Knowledge	2	0	0	0	
4.	AX5094	Value Education	2	0	0	0	
5.	AX5095	Constitution of India	2	0	0	0	
6.	AX5096	Pedagogy Studies	2	0	0	0	
7.	AX5097	Stress Management by Yoga	2	0	0	0	
8.	AX5098	Personality Development Through Life Enlightenment Skills	2	0	0	0	
9.	AX5099	Unnat Bharat Abhiyan	2	0	0	0	
		Total Credits				**0**	

EMPLOYABILITY ENHANCEMENT COURSES (EEC)

Sl.No	COURSE CODE	Course Title	Periods per week			Credits	Semester
			Lecture	Tutorial	Practical		
1	PS5212	Mini Project	0	0	4	2	3
2	PS5311	Project Phase I	0	0	12	6	3
3	PS5411	Project Phase II	0	0	24	12	4
					Total Credits:	**20**	

SUMMARY

	POWER SYSTEMS ENGINEERING					
	Subject Area	Credits per Semester				Credits Total
		I	II	III	IV	
1.	FC	00	00	00	00	00
2.	PCC	16	14	00	00	30
3.	PEC	03	06	06	00	15
4.	RMC	02	00	00	00	02
5.	OEC	00	00	03	00	03
6.	EEC	00	02	06	12	20
6.	Non Credit/Audit Course	✓	✓	00	00	
	Total Credit	**21**	**22**	**15**	**12**	**70**

PS5101 **POWER SYSTEM ANALYSIS** **L T P C**
3 1 0 4

COURSE OBJECTIVES

Students will be able to:

- Study various methods of load flow and their advantages and disadvantages
- Study optimal power flow solutions in detail.
- Understand power system security concepts and study the methods to rank the contingencies
- Analyze the role of generation scheduling in day-to-day operation of power system.
- Understand need of state estimation and study simple algorithms for state estimation

UNIT I POWER FLOW ANALYSIS 12

Overview of Newton-Raphson, Gauss – Seidel, Fast Decoupled Power Flow method, convergence properties, handling Q-max violation in constant matrix, inclusion of frequency effects, AVR in load flow, handling of discrete variable in load flow-introduction to restructured power system

UNIT II OPTIMAL POWER FLOW 12

Problem statement; Solution of Optimal Power Flow (OPF) – The gradient method, Newton's method, Linear Sensitivity Analysis; LP methods – With real power variables only – LP method with AC power flow variables and detailed cost functions; Security constrained Optimal Power Flow; Interior point algorithm; Bus Incremental costs.

UNIT III POWER SYSTEM SECURITY 12

Introduction to Power system security analysis and monitoring - DC Load flow - Factors affecting power system security - Contingency analysis for generator and line outages using linear sensitivity factors.

UNIT IV HYDROTHERMAL SCHEDULING PROBLEM 12

Hydrothermal scheduling problem: short term and long term-mathematical model, algorithm. Dynamic programming solution methodology for Hydro-thermal scheduling with pumped hydro plant: Optimization with pumped hydro plant-Scheduling of systems with pumped hydro plant during off-peak seasons: algorithm. Selection of initial feasible trajectory for pumped hydro plant- Pumped hydro plant as spinning reserve unit- generation of outage induced constraint-Pumped hydro plant as Load management plant.

UNIT V STATE ESTIMATION 12

Need for power system state estimation- Network observability – DC state estimation model- State estimation of power system – Methods of state estimation: Least square state estimation, weighted least square state estimation, Maximum likelihood- Bad data detection and identification.

TOTAL: 60 PERIODS

COURSE OUTCOMES

Students will be able to:

CO1: calculate voltage phasors at all buses, given the data using various methods of load flow

CO2: calculate OPF solutions for economic operation of power system

CO3: Rank various contingencies according to their severity

CO4: Analyze the optimal scheduling of power system with various generation mix

CO5: Estimate the bus voltage phasors given various quantities viz. power flow, voltages, taps, CB status etc.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓									
CO2	✓	✓	✓									
CO3	✓	✓	✓	✓								
CO4	✓	✓	✓	✓								
CO5	✓	✓	✓	✓								

REFERENCES

1. Allen.J.Wood and Bruce F.Wollenberg, 'Power Generation, Operation and Control', JohnWiley & Sons, Inc., 2003.
2. P. Kundur, 'Power System Stability & Control', McGraw Hill Publications,USA, 2006
3. Ali Abur & Antinio Gomez Exposito, 'Power System State Estimation Theory &Implementation', Marcel Dekker, Inc., Newyork,USA,2004.
4. Olle. I. Elgerd, 'Electric Energy Systems Theory – An Introduction', Tata McGraw HillPublishing Company Ltd,New Delhi, Second Edition, 2003.
5. D.P. Kothari and I.J. Nagrath, 'Modern Power System Analysis', Fourth Edition, TataMcGraw Hill Publishing Company Limited,New Delhi, 2011.
6. M.A.Pai," Computer Techniques in Power System Analysis",Tata McGraw-Hill Publishing Company Limited, New Delhi, 2006.

PS 5151 **ANALYSIS AND COMPUTATION OF ELECTROMAGNETIC TRANSIENTS IN POWER SYSTEMS** **L T P C 3 1 0 4**

COURSE OBJECTIVES

- To impart in depth knowledge about various power system transients and analyze the travelling wave phenomena.
- To impart knowledge on the EMTP Type modelling of overhead lines and underground cables.
- To impart knowledge on the EMTP Type modelling of transformers.
- To coordinate the insulation of power system and protective devices.
- To describe the methodology for computing the transients in power systems.

UNITI REVIEW OF TRAVELLING WAVE PHENOMENA 12

Lumped and Distributed Parameters – Wave Equation – Reflection, Refraction, Behavior 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 byfault; very fast transient overvoltage(VFTO).

UNIT II PARAMETERS AND MODELLING OF OVER HEADLINES AND UNDER GROUND CABLES 12

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 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 12

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 12

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 12

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: 60 PERIODS

COURSE OUTCOMES

Students will be able to:

CO1: Understand and analyse the different types of transients.

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.

MAPPING

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓							
CO2	✓	✓	✓	✓	✓							
CO3	✓	✓	✓	✓	✓							
CO4	✓	✓	✓	✓	✓							
CO5	✓	✓	✓	✓	✓							

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. Pritindra Chowdhari, “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.

PS5102 **POWER SYSTEM DYNAMICS** **L T P C**
3 1 0 4

COURSE OBJECTIVES

- To impart knowledge on dynamic modelling of a synchronous machine in detail
- To describe the modelling of excitation and speed governing system in detail.
- To understand the fundamental concepts of small disturbance stability of dynamic systems.
- Enable the students to evaluate rotor angle stability by explicit and implicit methods of integration.
- To expose the students to basic concepts of voltage stability.

UNIT I SYNCHRONOUS MACHINE MODELLING 12

Schematic Diagram, Physical Description: armature and field structure, machines with multiple pole pairs, mmf waveforms, direct and quadrature axes, Mathematical Description of a Synchronous Machine: Basic equations of a synchronous machine: stator circuit equations, stator self, stator mutual and stator to rotor mutual inductances, dq0 Transformation: flux linkage and voltage equations for stator and rotor in dq0 coordinates, electrical power and torque, physical interpretation of dq0 transformation, Equivalent Circuits for direct and quadrature axes, Steady-state Analysis: Voltage, current and flux-linkage relationships, Phasor representation,Rotor angle,

Steady-state equivalent circuit, Computation of steady-state values, Equations of Motion: Swing Equation, calculation of inertia constant, Representation in system studies, Synchronous Machine Representation in Stability Studies: Simplifications for large-scale studies

UNIT II MODELLING OF EXCITATION AND SPEED GOVERNING SYSTEMS 12

Excitation System Requirements; Elements of an Excitation System; Types of Excitation System; Control and protective functions; IEEE (1992) block diagram for simulation of excitation systems. Turbine and Governing System Modelling: Functional Block Diagram of Power Generation and Control, Schematic of a hydroelectric plant, classical transfer function of a hydraulic turbine (no derivation), special characteristic of hydraulic turbine, electrical analogue of hydraulic turbine, Governor for Hydraulic Turbine: Requirement for a transient droop, Block diagram of governor with transient droop compensation, Steam turbine modelling: Single reheat tandem compounded type only and IEEE block diagram for dynamic simulation; generic speed-governing system model for normal speed/loadcontrol function.

UNIT III SMALL-SIGNAL STABILITY ANALYSIS 12

Classification of Stability, Basic Concepts and Definitions: Rotor angle stability, The Stability Phenomena. Fundamental Concepts of Stability of Dynamic Systems: State- space representation, stability of dynamic system, Linearization, Eigen properties of the state matrix: Eigen values and eigenvectors, modal matrices, Eigen value and stability, mode shape and participation factor. Single-Machine Infinite Bus (SMIB) Configuration: Classical Machine Model stability analysis with numerical example, Effects of Field Circuit Dynamics: synchronous machine, network and linearized system equations, block diagram representation with K- constants; expression for K-constants (no derivation), effect of field flux variation on system stability: analysis with numerical example. Effects Of Excitation System-Enhancement of small signal stability

UNIT IV TRANSIENT STABILITY ANALYSIS 12

Review of numerical integration methods: Euler and Fourth Order Runge-Kutta methods, Numerical stability and implicit methods, Interfacing of Synchronous machine (variable voltage) model to the transient stability algorithm (TSA) with partitioned **–** explicit and implicit approaches – Interfacing SVC with TSA-Methods To Enhance TransientStability.

UNIT V VOLTAGE STABILITY ANALYSIS 12

Classification Of Voltage Stability-Basic Concept Related To Voltage Stability: Transmission SystemCharacteristics, Generator Characteristics, Load Characteristics, Characteristics Of Reactive Compensating Devices- Voltage Collapse: Typical Scenario Of Voltage Collapse, Voltage Factor That Affect Voltage Stability-Voltage Stability Analysis: Mode Dynamic Analysis, Static Analysis-Prevention Of Voltage Collapse.

TOTAL: 60 PERIODS

COURSE OUTCOMES

Students will be able to:

CO1: Model the synchronous machine for stability analysis.
CO2: Model of excitation and speed governing system for stabilityanalysis.
CO3: Analyze the small signal stability of power systems with controllers.
CO4: Analyze the rotor angle stability of the system stability by explicit and implicit methods of integration.

CO5: Investigate voltage stability of power system.

MAPPING

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓							
CO2	✓	✓	✓	✓	✓							
CO3	✓	✓	✓	✓	✓			✓				
CO4	✓	✓	✓	✓	✓							
CO5	✓	✓	✓	✓	✓	✓						✓

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1. R.Ramanujam," Power System Dynamics Analysis and Simulation, PHI Learning Private Limited, Second print, New Delhi,2013
2. P. Kundur, "Power System Stability and Control", McGraw-Hill,1993.
3. P. W. Sauer and M. A. Pai," Power System Dynamics and Stability", Stipes Publishing Co,2007
4. IEEE Committee Report, "Dynamic Models for Steam and Hydro Turbines in Power System Studies", IEEE Trans., Vol.PAS-92, pp 1904-1915, November/December, 1973.on Turbine-GovernorModel.
5. P.M Anderson and A.A Fouad, "Power System Control and Stability", Iowa State University Press,Ames,Iowa, 1976

RM5151 RESEARCH METHODOLOGY AND IPR LT P C
2 0 0 2

COURSE OBJECTIVES:

To impart knowledge and skills required for research and IPR:

- Problem formulation, analysis and solutions.
- Technical paper writing / presentation without violating professional ethics
- Patent drafting and filing patents.

UNIT I RESEARCH PROBLEM FORMULATION 6

Meaning of research problem- Sources of research problem, criteria characteristics of a good research problem, errors in selecting a research problem, scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, necessary instrumentations

UNIT II LITERATURE REVIEW 6

Effective literature studies approaches, analysis, plagiarism, and research ethics.

UNIT III TECHNICALWRITING /PRESENTATION 6

Effective technical writing, how to write report, paper, developing a research proposal, format of research proposal, a presentation and assessment by a review committee.

UNIT IV INTRODUCTION TO INTELLECTUAL PROPERTY RIGHTS (IPR) 6

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

UNIT V INTELLECTUAL PROPERTY RIGHTS (IPR) 6

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications. New Developments in IPR: Administration of Patent System, IPR of Biological Systems, Computer Software etc.

Traditional knowledge Case Studies, IPR and IITs.

TOTAL: 30 PERIODS

COURCE OUTCOMES:

1. Ability to formulate research problem
2. Ability to carry out research analysis
3. Ability to follow research ethics
4. Ability to understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity
5. Ability to understand about IPR and filing patents in R & D.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓										
CO2	✓											
CO3	✓							✓				
CO4	✓				✓							
CO5	✓					✓						✓

REFERENCES:

1. Asimov, "Introduction to Design", Prentice Hall, 1962.
2. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
3. Mayall, "Industrial Design", McGraw Hill, 1992.
4. Niebel, "Product Design", McGraw Hill, 1974.
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PS5111 **POWER SYSTEM SIMULATION LABORATORY** **L T P C**
0 0 4 2

COURSE OBJECTIVES

- To have hands on experience on various system studies and different techniques used for system operation and planning.
- To have Hands-on experience on various power system studies using user developed programs and validation of results using application software packages.
- To gain practical knowledge on load flow analysis solved by various methods.
- To do stability analysis on single machine and multi machine configuration.
- To calculate Available Transfer Capacity and Locational marginal pricing for Deregulated power system.

1. Power flow analysis by Newton-Raphson and Fast decoupled methods.
2. Contingencyanalysis:Generatorshiftfactorsandlineoutagedistributionfactors
3. State estimation of power systems.
4. Small-signal stability analysis of single machine-infinite bus system using classical machine model
5. Small-signal stability analysis of multi-machine configuration with classical machine model
6. Induction motor starting analysis
7. Available Transfer Capability calculation using an existing load flow program
8. Computation of harmonic indices generated by a rectifier feeding a R-L load
9. Design of active filter for mitigating harmonics.
10. Analysis of switching surge using EMTP: Energisation of a long distributed- parameter line
11. Analysis of switching surge using EMTP : Computation of transient recovery voltage for short line fault.
12. Locational Marginal Pricing computation of Restructured power systems

TOTAL: 60 PERIODS

COURSE OUTCOMES

CO1: Students will be able to gain Hands-on experience on various power system studies using user developed programs and validation of results using application software packages.

CO2:Students can gain practical knowledge on load flow analysis solved by various methods.

CO3: Students will be able to do stability analysis on single machine and multi machine configuration.

CO4: Students have learnt to calculate Available Transfer Capacity and Locational marginal pricing for Deregulated power system.

CO5: Experiments were conducted to mitigate and compute Harmonic indices.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓							
CO2	✓	✓	✓	✓	✓							
CO3	✓	✓	✓	✓	✓							

CO4	✓	✓	✓	✓	✓							
CO5	✓	✓	✓	✓	✓							

PW5261 **RENEWABLE ENERGY LABORATORY** **LT P C**
0 0 4 2

COURSE OBJECTIVES

Students will be able to:

- Study the performance of various renewable energy sources.
- Obtain hands-on experience on various wind turbine operation.
- Analyze the grid integration issues of renewable energy sources.
- To analyze the performance characteristics of DFIG and PMSG.
- To design and model PV system integration with grid.

1. Performance characteristics of solar PV panel.
2. Performance of PV panel in series and parallel combination.
3. VI characteristics of fuel cell.
4. Performance characteristics of self- excited Induction Generator.
5. Performance characteristics of DFIG.
6. Performance characteristics of PMSG.
7. MPPT tracking of DFIG based WT.
8. MPPT tracking of PMSG based WT.
9. Grid integration of RES.

TOTAL 60 PERIODS

COURSE OUTCOMES

CO1: Students will understand the characteristics of various renewable energy sources.
CO2: Students will be able to program different MPPT algorithm and understand their merits and demerits
CO3: Students will learn control of DFIG .
CO4: Students will learn control of PMSG .
CO5: Students will design and model PV system integration with grid.

MAPPING

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	✓				✓	✓	✓	✓	✓	✓	✓	
CO2	✓				✓	✓	✓	✓	✓	✓	✓	
CO3	✓				✓	✓	✓	✓	✓	✓	✓	
CO4	✓				✓	✓	✓	✓	✓	✓	✓	
CO5	✓				✓	✓	✓	✓	✓	✓	✓	✓

PS5201 ADVANCED POWER SYSTEM PROTECTION **L T P C**
3 0 0 3

COURSE OBJECTIVES

Students will be able to:

- illustrate concepts of transformer protection
- describe about the various schemes of Over current protection
- analyze distance and carrier protection
- familiarize the concepts of Bus bar protection and Numerical protection
- to understand the concepts of substation automation

UNIT I OVER CURRENT & EARTH FAULTPROTECTION 9

Zones of protection – Primary and Backup protection – operating principles and Relay Construction. Time – Current characteristics-Current setting – Time setting-Over current protective schemes – Concept of Coordination - Protection of parallel / ring feeders - Reverse power or directional relay – Polarisation Techniques – Cross Polarisation – Quadrature Connection -Earth fault and phase fault protection - Combined Earth fault and phase fault protection scheme - Phase fault protective - scheme directional earth fault relay - Static over current relays – Numerical over - current protection; numerical coordination example for a radialfeeder

UNIT II TRANSFORMER &BUSBAR PROTECTION 13

Types of transformers –Types of faults in transformers- Types of Differential Protection – High Impedance – External fault with one CT saturation – Actual behaviors of a protective CT - Circuit model of a saturated CT - Need for high impedance – Disadvantages - Percentage Differential Bias Characteristics – Vector group & its impact on differential protection - Inrush phenomenon – Zero Sequence filtering – High resistance Ground Faults in Transformers – Restricted Earth fault Protection - Inter-turn faults in transformers – Incipient faults in transformers - Phenomenon of over- fluxing in transformers – Transformer protection application chart. Differential protection of busbars- external and internal fault - Supervisory relay-protection of three – Phase busbars - Numerical examples on design of high impedance busbar differential scheme –Biased Differential Characteristics – Comparison between Transformer differential & Busbar differential.

UNIT III DISTANCE AND CARRIER PROTECTION OFTRANSMISSION LINES 9

Braw back of over – Current protection – Introduction to distance relay – Simple impedance relay – Reactance relay – Mho relays – Disadvantages – Quadrilateral Characteristics - Comparison of distance relay – Distance protection of a three – Phase line-reasons for inaccuracy of distance relay reach - Three stepped distance protection – Effect of Source impedance & Earthing – Effect of Power Swing - Need for carrier – Aided protection – Various options for a carrier - Coupling and trapping the carrier into the desired line section - Unit type carrier aided directional comparison relaying – Carrier aided distance schemes – Permissive Under reach & Over reach schemes - Acceleration of Zone II faults - Numerical example for a typical distance protection scheme for a transmission line.

UNITIV GENERATORPROTECTION 8

Electrical circuit of the generator –Various faults and abnormal operating conditions – Stator Winding Faults – Protection against Stator (earth) faults – third harmonic voltage protection - Rotor fault – Abnormal operating conditions - Protection against Rotor faults – Potentiometer Method – injection method – Pole slipping – Loss of excitation – Protection against Mechanical faults; Numerical examples for typical generator protection schemes

UNIT V SUBSTATION AUTOMATION 6

Introduction to Substation Automation – Topology – Hardware Implementation – Introduction to Digital Substation – Importance of Communications in Digital world – OSI Layer – Ethernet Communication – Introduction to Analog to Digital Transformation – Merging Units (MU) - Introduction to IEC 61850 – Advantages of IEC 61850

TOTAL: 45 PERIODS

COURSE OUTCOMES

CO1: Understand the various schemes available in Transformer and Bus bar protection
CO2: Gain knowledge on over current protection.
CO3: Attain knowledge about Distance and Carrier protection for transmission lines.
CO4: Understand the concepts of generator protection.
CO5: Attain basic knowledge on substation automation.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓		✓		✓				
CO2	✓	✓	✓	✓		✓		✓				
CO3	✓	✓	✓	✓		✓		✓				
CO4	✓	✓				✓		✓				
CO5	✓					✓		✓				

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2. Badri Ram and D.N. Vishwakarma, “Power System Protection and Switchgear”, Tata McGraw- Hill Publishing Company,2002.
3. P.Kundur, “Power System Stability and Control”, McGraw-Hill,1993.
4. Protective Relaying for Power System II Stanley Horowitz,IEEE press , New York,2008
5. Network Protection & Automation Guide, Edition May 2011 – Alstom Grid.
6. T.S.M. Rao, Digital Relay / Numerical relays, Tata McGraw Hill, New Delhi,1989

PS5251 **HVDC AND FACTS**

L	T	P	C
3	1	0	4

COURSE OBJECTIVES

- To impart knowledge on the need for HVDC and FACTS.
- To impart in depth knowledge the operation, modelling and control of thyristor based FACTS controllers.
- To have an in-depth knowledge on the operation, modelling and control of LCC based HVDC link.
- To have an in-depth knowledge on the operation, modelling and control of VSC based HVDC link and FACTS controllers.
- To analyze the interaction of AC- DC systems through Power flow analysis.

UNIT I INTRODUCTION **12**

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 **12**

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 **12**

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 AND HVDC CONTROLLERS **12**

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 and IPFC for power flow and transient stability studies- Applications VSC based HVDC: Operation, Modelling for steady state and dynamic studies.

UNIT V POWER FLOW ANALYSIS OF AC/DC SYSTEMS **12**

Per unit system for DC Quantities - Modelling of DC links - Solution of DC load flow-Solution of AC-DC power flow: Sequential and Simultaneous methods.

TOTAL: 60 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.

MAPPING

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓							
CO2	✓	✓	✓	✓	✓							
CO3	✓	✓	✓	✓	✓			✓				
CO4	✓	✓	✓	✓	✓							
CO5	✓	✓	✓	✓	✓	✓						✓

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., New Delhi, 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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8. A.T.John, “Flexible AC Transmission System”, Institution of Electrical and Electronic Engineers (IEEE), 1999.
9. Narain G.Hingorani, Laszio. Gyugyl, “Understanding FACTS Concepts and Technologyof Flexible AC Transmission System”, Standard Publishers, Delhi 2001.

PS5252	RESTRUCTURED POWER SYSTEM	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

Students will be able to:

- describe various types of deregulated markets in power system.
- describe the technical and non-technical issues in deregulated power industry.
- classify different market mechanisms and summarize the role of various entities in the market.
- analyze the energy and ancillary services management in deregulated power industry.
- understand the restructuring framework US and Indian power sector

UNIT I INTRODUCTION 9

Reasons for restructuring - Understanding the restructuring process - objectives of deregulation of various power systems across the world - Consumer behavior - Supplier behavior - Market equilibrium - Short-run and Long-run costs - Various costs of production. The Philosophy of Market Models**:** Market models based on contractual arrangements - Market architecture - .

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 - The Nordic power 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

TOTAL: 45 PERIODS

COURSE OUTCOMES

Students will be able to:

CO1: describe the requirement for deregulation of the electricity market and the philosophy of various market models

CO2: analyze the 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

CO5: understand the framework of Indian power sector

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓					✓	✓					
CO2	✓	✓	✓			✓						
CO3	✓	✓	✓			✓						
CO4	✓	✓	✓			✓						
CO5	✓					✓	✓	✓				

REFERENCES

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PS5211 **POWER SYSTEM PROTECTION LABORATORY** **L T P C**
0 0 4 2

COURSE OBJECTIVES

Students will be able to

- To analyze feature of V&I and verify with DSO
- To analyze the different characteristics curves
- To analyze the relay with inrush phenomena
- To test the differential protection by PSCAD/EMTDC
- To study the Numerical Transformer / Distance Protection with Relay test kit.

1. Understanding feature of injection of V&I along with control parameters (Magnitude, Frequency, Phase angle) and verify with DSO
2. Ramping feature of V&I and verify with DSO.
3. Testing Different characteristics of curve (IEC – NI, VI, LTI, and EI).
4. Verification of Non-directional OC/EF along with different RCA/MTAwith Inrush phenomena.
5. Analysis of High impedance and Low impedance biased current differential protection for transformers.
6. Testing of Low impedance biased Current Differential protection with Simulation of excitation failure of generator by PSCAD/EMTDC and implementation of protection settings and verifying relay characteristics.
7. Testing of relay characteristics of Out of step considering Generator side fault and Power swing of Power system side.
8. Study of Numerical Transformer / Distance Protection with Relay test kit.
9. Hardware-in-loop simulation with generator protection relay and real-time digital simulator.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

CO1: Ability to analyze feature of V&I and verify with DSO
CO2: Ability to analyze the different characteristics curves
CO3: Ability to analyze the relay with inrush phenomena
CO4: Ability to test the differential protection by PSCAD/EMTDC
CO5: Ability to test the Numerical Transformer / Distance Protection with Relay test kit.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓		✓	✓	✓				✓			
CO2	✓		✓	✓	✓				✓			
CO3	✓		✓	✓	✓				✓			
CO4	✓		✓	✓	✓				✓			
CO5	✓		✓	✓	✓				✓			

PE5161	POWER CONVERTERS LABORATORY	L	T	P	C
		0	0	4	2

COURSE OBJECTIVES:

- To provide the requisite knowledge necessary to appreciate the dynamical equations involved in the analysis of different PED configurations.
- To understand the dynamics and different operating modes of power converters studied in the core courses on power converters.
- To analyze, design and simulate different rectifier circuits for generic load and for machine loads
- To simulate different inverter topologies.
- To formulate, design, simulate power supplies for generic load and for machine loads.

LIST OF EXPERIMENTS:

1. Simulation of single phase half wave controlled converter fed RLE load.
2. Simulation of single phase fully controlled converter fed RLE load.
3. Simulation of three phase half controlled converter fed RL load.
4. Simulation of three phase fully controlled converter fed RL load.
5. Study of single phase Fully Controlled Rectifier, Half Controlled Rectifier with different Loads.
6. Study of Three phase Fully Controlled Rectifier, Half Controlled Rectifier with different Loads.
7. Simulation of single phase VSI fed RL/RC load.
8. Design of UPS.
9. Design of SMPS.
10. Simulation of multilevel inverter topologies.

TOTAL : 60 PERIODS

COURSE OUTCOMES:

CO1:Ability to solve dynamic equations involved in power electronics.

CO2:Ability to acquire and apply knowledge of mathematics and converter/machine dynamics in Electrical engineering.

CO3:Ability to model and analyze different rectifier circuits using computational software and to understand their various operating modes.

CO4:Ability to model and analyze different rectifier circuits using computational software and to understand their various operating modes.

CO5:Ability to formulate, design, simulate power supplies for generic load and for machine loads.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓			✓				✓			
CO2	✓	✓			✓				✓			
CO3	✓	✓			✓				✓			
CO4	✓	✓			✓				✓			
CO5	✓	✓			✓				✓			

REFERENCES:

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2. Rashid M.H., “Power Electronics Circuits, Devices and Applications ", Prentice Hal India, New Delhi, 1995.

PS5001 POWER SYSTEM PLANNING AND RELIABILITY **L T P C**
3 0 0 3

COURSE OBJECTIVES

- To introduces the objectives of Load fore casting.
- To study the fundamentals of Generation system, transmission system and
- Distribution system reliability analysis
- To illustrate the basic concepts of Expansion planning
- To understand the overview of distribution system planning

UNIT I LOAD FORECASTING **9**

Objectives of forecasting - Load growth patterns and their importance in planning - Load forecasting Based on discounted multiple regression technique-Weather sensitive load forecasting-Determination of annual forecasting-Use of AI in load forecasting.

UNIT II GENERATION SYSTEM RELIABILITY ANALYSIS **9**

Probabilistic generation and load models- Determination of LOLP and expected value of demand not served –Determination of reliability of ISO and interconnected generation systems.

UNIT III TRANSMISSION SYSTEM RELIABILITY ANALYSIS **9**

Deterministic contingency analysis-probabilistic load flow-Fuzzy load flow probabilistic transmission system reliability analysis-Determination of reliability indices like LOLP and expected value of demand notserved.

UNIT IV EXPANSIONPLANNING **9**

Basic concepts on expansion planning-procedure followed for integrate transmission system planning, current practice in India-Capacitor placer problem in transmission system and radial distributions system.

UNIT V DISTRIBUTION SYSTEMPLANNINGOVERVIEW **9**

Introduction, sub transmission lines and distribution substations-Design primary and secondary systems-distribution system protection and coordination of protective devices.

TOTAL: 45 PERIODS

COURSE OUTCOMES

Students will be able to:

CO1: Develop the ability to learn about load forecasting.
CO2: learn about reliability analysis of ISO and interconnected systems.
CO3: Understand the concepts of Contingency analysis and Probabilistic Load flow analysis
CO4: Understand the concepts of Expansion planning
CO5: Understand the fundamental concepts of the Distribution system planning

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓				✓			
CO2	✓	✓	✓	✓	✓				✓			
CO3	✓	✓	✓	✓	✓				✓			
CO4	✓	✓	✓	✓	✓				✓			
CO5	✓	✓	✓	✓	✓				✓			

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2. Power System Planning - R.L. Sullivan, Tata McGraw Hill Publishing CompanyLtd.
3. Modern Power System Planning – X. Wang & J.R. McDonald, McGraw Hill BookCompany
4. Electrical Power Distribution Engineering - T. Gonen, McGraw Hill BookCompany
5. Generation of Electrical Energy – B.R. Gupta, S. ChandPublication

PS5002 INDUSTRIAL POWER SYSTEM ANALYSIS AND DESIGN

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

Students will be able to:

- To impart knowledge on Motor Starting Studies.
- To understand the need for power factor correction and analyse the various methods that are used in the Power Factor Correction studies.
- To learn about the sources of harmonics, evaluate the harmonics present in the power system and mitigate them by filters.
- To analyse the sources that can cause the voltage flicker and find solutions to minimize the flicker.
- To impart knowledge on the ground grid analysis.

UNIT I MOTOR STARTING STUDIES **9**

Introduction-Evaluation Criteria-Starting Methods-System Data-Voltage Drop Calculations-Calculation of Acceleration time-Motor Starting with Limited-Capacity Generators-Computer-Aided Analysis-Conclusions.

UNIT II POWER FACTOR CORRECTION STUDIES 9

Introduction-System Description and Modeling-Acceptance Criteria-Frequency Scan Analysis-Voltage Magnification Analysis-Sustained Overvoltage's-Switching Surge Analysis-Back-to-Back Switching-Summary and Conclusions.

UNIT III HARMONIC ANALYSIS 9

Harmonic Sources-System Response to Harmonics-System Model for Computer-Aided Analysis-Acceptance Criteria-Harmonic Filters-Harmonic Evaluation-Case Study-Summary and Conclusions.

UNIT IV FLICKER ANALYSIS 9

Sources of Flicker-Flicker Analysis-Flicker Criteria-Data for Flicker analysis- Case Study-Arc Furnace Load-Minimizing the Flicker Effects-Summary.

UNIT V GROUND GRID ANALYSIS 9

Introduction-Acceptance Criteria-Ground Grid Calculations-Computer-Aided Analysis - Improving the Performance of the Grounding Grids-Conclusions.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Students will be able to:

CO1: perform motor starting studies.
CO2: To model and carry out power factor correction studies.
CO3: Perform harmonic analysis and reduce the harmonics by using filters.
CO4: Carry out the flicker analysis by proper modeling of the load and its minimization.
CO5: Design the appropriate ground grid for electrical safety.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓				✓			
CO2	✓	✓	✓	✓	✓				✓			
CO3	✓	✓	✓	✓	✓				✓			
CO4	✓	✓	✓	✓	✓				✓			
CO5	✓	✓	✓	✓	✓				✓			

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PS5003 **ADVANCED POWER SYSTEM DYNAMICS** **L T P C**

3 0 0 3

COURSE OBJECTIVES

- To impart knowledge on sub-synchronous resonance and oscillations.
- To analyze impact of generation and transmission aspects on voltage stability
- To analyze impact of load aspects on voltage stability
- To familiarize the methods that mitigates voltage instability.
- To familiarize the methods that enhances the small signal stability of power system.

UNIT I SUBSYNCHRONOUS RESONANCE (SSR) AND OSCILLATIONS 9

Subsynchronous Resonance (SSR) – Types of SSR - Characteristics of series –Compensated transmission systems –Modelling of turbine-generator-transmission network- Self-excitation due to induction generator effect – Torsional interaction resulting in SSR – Methods of analyzing SSR – Numerical examples illustrating instability of sub synchronous oscillations –time-domain simulation of sub synchronous resonance – EMTP with detailed synchronous machine model- Turbine Generator Torsional Characteristics: Shaft system model – Examples of torsional characteristics – Torsional Interaction with Power System Controls: Interaction with generator excitation controls – Interaction with speed governors – Interaction with nearby DC converters.

UNIT II TRANSMISSION ANDGENERATION ASPECTS OF VOLTAGE STABILITY ANALYSIS 9

Review of transmission aspects – Generation Aspects: Review of synchronous machine theory Voltage and frequency controllers – Limiting devices affecting voltage stability – Voltage- reactive power characteristics of synchronous generators – Capability curves – Effect of machine limitation on deliverable power.

UNIT III LOAD ASPECTS OF VOLTAGE STABILITY ANALYSIS 9

Load Aspects – Voltage dependence of loads – Load restoration dynamics – Induction motors – Load tap changers – Thermostatic load recovery – General aggregate load models.

UNIT IV INSTABILITY MECHANISM AND COUNTER MEASURES TO VOLTGAE STABILITY 9

Types of Counter measures – Classification of Instability Mechanisms – Examples of Short term Voltage Instability- Counter measures to Short – term Instability – Case studies of Long Term voltage Instability – Corrective Actions against Long-term Instability – Problems.

UNIT V SMALL SIGNAL STABILITY ANALYSIS AND ENHANCEMENT 9

Multi machine small signal stability analysis - Effects Of Excitation System - Power System Stabilizer: Block diagram with AVR and PSS, Illustration of principle of PSS application with numerical example, Block diagram of PSS with description, system state matrix including PSS, analysis of stability with numerical example. Multi-Machine Configuration: Equations in a common reference frame, equations in individual machine rotor coordinates, illustration of formation of system state matrix with classical model and variable voltage behind transient reactant model of synchronous machines, illustration of stability analysis using a numerical example. Principle behind small-signal stability improvement methods: delta-omega and delta P-omega stabilizers

TOTAL : 45 PERIODS

COURSE OUTCOMES

Students will be able to:

CO1: Understand the concepts behind sub-synchronous resonance and detect the SSR by suitable modeling
CO2: Analyze the effect of generation and transmission system on voltage stability.
CO3: Analyze the effect of load dynamics on power system voltage stability.
CO4: Analyze and enhance the voltage stability of the sample power system.
CO5: Design a damping controller to enhance small signal stability of the power system.

MAPPING

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓							
CO2	✓	✓	✓	✓	✓							
CO3	✓	✓	✓	✓	✓			✓				
CO4	✓	✓	✓	✓	✓							
CO5	✓	✓	✓	✓	✓	✓						✓

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1. R.Ramanujam," Power System Dynamics Analysis and Simulation, PHI Learning Private Limited, New Delhi,2009
2. T.V. Cutsem and C.Vournas, "Voltage Stability of Electric Power Systems", Kluwer publishers,1998.
3. P. Kundur, Power System Stability and Control, McGraw-Hill,1993.
4. H.W. Dommel and N.Sato, "Fast Transient Stability Solutions," IEEE Trans., Vol. PAS-91, pp, 1643-1650, July/August1972.
5. Roderick J.Frowd and J. C. Giri, "Transient stability and Long term dynamics unified", IEEE Trans., Vol 101, No. 10, October1982.
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PS5004 POWER SYSTEM STATE ESTIMATION LT P C
3 0 0 3

COURSE OBJECTIVES

- To introduce the state estimation on DC network.
- To impart in-depth knowledge on power system state estimation.
- To study alternative formulations of WLS state estimation.
- To get insight of network observability.
- To gain knowledge on bad data deduction and identification.

UNIT I INTRODUCTION TO STATE ESTIMATION 9

Need for state estimation – Measurements – Noise - Measurement functions - Measurement

Jacobian – Weights - Gain matrix - State estimation as applied to DC networks - Comparison of Power flow and State Estimation problems - Energy Management System.

UNIT II WEIGHTED LEAST SQUARE ESTIMATION 9

Modeling of transmission lines - Shunt capacitors and reactors - Tap changing and phase shifting transformers - loads and generators - Building network models - Maximum likelihood estimation - Measurement model and assumptions - WLS State Estimation Algorithm - Measurement functions - Measurement Jacobian matrix - Gain matrix - Cholesky decomposition and performing forward and backward substitutions - Decoupled formulation of WLS State estimation - DC State estimation model - Role of Phasor Measurement Units (PMU) in state estimation.

UNIT III ALTERNATIVE FORMULATION OF WLS STATE ESTIMATION 9

Weakness of normal equation formulation, Orthogonal factorization, Hybrid method, Method of Peters and Wilkinsons, Equality constraints WLS State estimation, Augmented matrix approach, Blocked formulation and comparison of techniques.

UNIT IV NETWORK OBSERVABILITY ANALYSIS 9

Network and graphs, Network matrices, loop equations, Methods Observability analysis, Numerical Method based on Nodal Variable formulation and branch variable formulation, Topological Observability analysis, Determination of critical measurements – Role of PMU in network observability.

UNIT V BAD DATA DETECTION AND IDENTIFICATION 9

Properties of measurement residuals - Classification of measurements - Bad data detection and identification using Chi-squares distribution and normalized residuals - Bad data identification - Largest normalized residual test and Hypothesis testing identification. bad data detection using PMU.

TOTAL: 45 PERIODS

COURSE OUTCOMES

Students will be able to:

CO1: Gain knowledge about state estimation
CO2: Gain knowledge on weighted least square estimation.
CO3: Learn alternative formulation of WLS state estimation.
CO4: Get insight of network observability.
CO5: Gain knowledge on bad date detection and identification.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓										
CO2	✓	✓			✓							
CO3	✓	✓			✓							
CO4	✓	✓			✓							
CO5	✓	✓	✓	✓	✓							

REFERENCES

1. Ali Abur and Antonio Gomez Exposito ,“Power System State Estimation Theory and Implementation”, Marcel Dekker, Inc., New York . Basel, 2004.

2. J J Grainger and W D Stevension, " Power System Analysis", McGraw-Hill, Inc., 1994.
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5. Felix L. Chernousko, " State Estimation for Dynamic Systems", CRC Press, 1993
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PS5071 APPLICATION OF AI TECHNIQUES TO POWER SYSTEMS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

- Formulating the optimization problems using ANN.
- Using appropriate ANN framework for solving power system problems.
- Using Fuzzy Logic for optimization problems
- Formulating the optimization problems using GA
- Applying different Artificial Intelligence techniques for optimizing power system problems.

UNIT I ARTIFICIAL NEURAL NETWORKS **9**

Introduction Models of Neuron Network – Architectures – Knowledge representation – Artificial Intelligence and Neural networks–Learning process – Error correction learning – Hebbian learning– Competitive learning – Boltzmann learning –Supervised learning – Unsupervised learning – Reinforcement learning – learning tasks

UNIT II ANN PARADIGMS **9**

Multi – layer perceptron using Back propagation Algorithm (BPA) – Self – Organizing Map (SOM) – Radial Basis Function Network – Functional Link Network (FLN) – Hopfield Network.

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.

UNIT IV GENETIC ALGORITHMS **9**

Introduction–Encoding – Fitness Function–Reproduction operators–Genetic Modeling – Genetic operators–Cross over – Single site cross over – Two point cross over – Multi point cross over – Uniform cross over – Matrix cross over–Cross over Rate –Inversion & Deletion – Mutation operator– Mutation – Mutation Rate–Bit–wise operators –Generational cycle – convergence of Genetic Algorithm.

UNIT V APPLICATIONS OF AI TECHNIQUES **9**

Load forecasting – Load flow studies – Economic load dispatch – Load frequency control – Single area system and two area system – Small Signal Stability (Dynamic stability) Reactive power control – speed control of DC and AC Motors.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Students will be able to:

CO1: Learn problem formulation using Artificial Neural Network.
CO2: Choose methodology suiting the problem statement.
CO3: Learn Fuzzy Logic based implementation of optimization problem
CO4: Learn problem formulation using Genetic Algorithm
CO5: Apply ANN, Fuzzy Logic and Genetic Algorithm for Power System Optimization Problem

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓		✓						✓	
CO2	✓	✓	✓	✓	✓						✓	
CO3	✓	✓	✓		✓						✓	
CO4	✓	✓	✓	✓	✓						✓	
CO5	✓	✓	✓	✓	✓						✓	

REFERENCES

1. S.Rajasekaran and G.A.V.Pai Neural Networks, Fuzzy Logic & Genetic Algorithms, PHI, New Delhi, 2003.
2. Rober J. Schalkoff, Artificial Neural Networks, Tata McGraw Hill Edition, 2011

PS5072 APPLICATION OF DSP TO POWER SYSTEM PROTECTION

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

- To expose the students to learn about DFT and Wavelet transforms.
- To provide an in-depth knowledge on the components used for the implementation of digital protection.
- To impart knowledge on different algorithms for digital protection of power system components.
- To implement digital protection for transformer.
- To understand different decision making methodologies in protective relays.

UNIT I DIGITAL SIGNAL PROCESSING TECHNIQUES 9

Sampling-Principle of scaling-aliasing-Decimation, Interpolation. Fourier and discrete Fourier transforms - Fast Fourier Transforms.-Wavelet transform -Numerical Algorithms

UNIT II DIGITAL PROTECTION 9

Digital Protection -performance and operational characteristics of digital protection. Basic components of digital relays -Signal conditioning sub systems -Conversion subsystem -digital relay subsystem-Digital relay as a unit.

UNIT III ALGORITHMIC TECHNIQUES 9

Finite difference techniques- Interpolation-Numerical differentiation-curve fitting and smoothing. Sinusoidal wave based algorithms -First and second derivative method -two and three sample technique .Walsh function analysis- least squares based methods-differential equation based techniques -Travelling wave protective schemes.FIR based algorithms-Least square curve fitting algorithm.

UNIT IV DIGITAL PROTECTION TECHNIQUES 9

Transformer protection- -Fourier based algorithm-basic hardware of microprocessor based transformer protection .Digital line differential scheme. Measurement algorithms for digital protection -power-voltage -current -Impedance -phase shift.

UNIT V DIGITAL PROTECTIVE RELAYS 9

Decision making in protective relays- Deterministic Decision Making - Statistical Hypotheses Testing - Decision Making with Multiple Criteria - Adaptive Decision Schemes .Elements of Fuzzy Logic in Protective Relays -Fuzzy Sets and Fuzzy Numbers -Boolean Versus Fuzzy Logic -Fuzzy Reasoning - Fuzzy Logic Applications for Protection and Control.

TOTAL: 45 PERIODS

COURSE OUTCOMES

CO1: The students will be able to apply DSP techniques for digital protection.
CO2: The students will be capable of decision making algorithm suitable for digital relaying applications.
CO3: The students will be able to employ FIR based algorithms for digital relaying.
CO4: The students will be able to do transformer protection using digital techniques.
CO5: The students will be able to perform coordinated operation of relays for specific purposes.

MAPPING

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓							
CO2	✓	✓	✓	✓	✓							
CO3	✓	✓	✓	✓	✓			✓				
CO4	✓	✓	✓	✓	✓							
CO5	✓	✓	✓	✓	✓	✓						✓

REFERENCES

1. J.L. Blackburn, Protective Relaying: Principles and Applications, Marcel Dekker, New York, 1987.
2. A.G. Phadke and J.S. Thorp, Computer Relaying for Power Systems, John Wiley & Sons, New York, 1988.
3. J.G. Proakis and D.G. Manolakis, 'Digital Signal Processing Principles, Algorithms

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PS5073 DISTRIBUTED GENERATION CONTROL AND AUTOMATION

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

Students will be able to:

- learn about distributed generation (DG) and distribution automation
- gain knowledge about planning and designing of distribution system
- understand the concepts of grid integration and control of DG
- familiarize the concepts of economic aspects of DG
- analyze the application of SCADA in automation

UNIT I DISTRIBUTED GENERATION 9

Introduction, Distributed Generation Definition, Distributed generation advantages, challenges and needs, Distributed Generation Units- Micro turbines, Reciprocating Engines, Wind generators, Photovoltaic generators, Hydro generation, Fuel cells, Biomass and other technologies. Energy Storage-batteries, Flywheels, Ultra Capacitors.

UNIT II GRID INTEGRATION AND CONTROL OF DG 9

Recent trends in power electronic DG interconnection. General power electronic DG interconnection topologies for various sources and control. Control of DG inverters, current control and DC voltage control for stand-alone and grid parallel operations. Protection of the converter, Control of grid interactive power converters, phase locked loops ,synchronization and phase locking techniques, current control, DC bus control during grid faults, converter faults during grid parallel and stand-alone operation.

UNIT III ISSUES AND ECONOMIC ASPECTS OF DG 9

Intentional and unintentional islanding of distribution systems. Passive and active detection of unintentional islands, non-detection zones. Reactive power support using DG. Power quality improvement using DG, Power quality issues in DG environment. Economic aspects of DG-Generation cost, investment, tariffs analysis. Hybrid energy systems. Distributed generation in the Indian scenario – case studies.

UNIT IV IMPLEMENTATION OF SCADA IN AUTOMATION 9

Introduction to SCADA, Monitoring and supervisory functions, SCADA applications in Utility Automation, SCADA System Components, RTU, IED, PLC, Communication Network, SCADA Server, SCADA/HMI Systems, Various SCADA architectures, single unified standard architecture-IEC 61850, SCADA Communication, open standard communication protocols.

UNIT V DISTRIBUTION AUTOMATION AND COMPONENTS 9

Distribution automation planning, communication, Wireless and wired Communications-DA Communication Protocols, Architectures and user interface, sensors, Supervisory Control and Data Acquisition Systems (SCADA), Case Studies.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Students will be able to:
CO1:describe the principle and operation of different distributed generation
CO2:Attain knowledge in grid integration of distributed generation and control and will enhance their capability of planning and designing of distribution system.
CO3:analyze the impact of distributed generators on the performance of distribution system
CO4: gain knowledge about SCADA in automation
CO5:familiarize with the components of distribution automation

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓	✓	✓	✓			✓					
CO3	✓	✓	✓	✓								
CO4	✓			✓		✓						
CO5	✓					✓						

REFERENCES

1. H. Lee Willis & Walter G. Scott, “Distributed Power Generation, Planning & Evaluation” CRC Press, Taylor & Francis Group, 2000.
2. D.Mukherjee, and S.Chakrabarti, ”Fundamentals of renewable energy systems", New Age International Pvt Ltd Publishers, 2007.
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PS5074 **OPTIMISATION TECHNIQUES** **L T P C**
3 0 0 3

COURSE OBJECTIVES

Students will be able to:

- understand the classification of optimization
- study the linear programming models and solution techniques
- study the different non-linear programming problem solution techniques
- understand the concept of dynamic programming
- study the fundamentals genetic algorithm and it applications.

UNITI INTRODUCTION **9**

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

UNITII LINEARPROGRAMMING (LP) **9**

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

UNITIII NONLINEAR PROGRAMMING **9**

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

UNITIV DYNAMICPROGRAMMING (DP) **9**

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

UNITV GENETICALGORITHM **9**

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

TOTAL: 45 PERIODS

COURSE OUTCOMES

Students will be able to:

CO1:learn about different classifications of optimization problems and techniques.
CO2:attain knowledge on linear programming concepts
CO3:understand the application of non-linear programming in optimization techniques
CO4:understand the fundamental concepts of dynamic programming
CO5:gain knowledge about Genetic algorithm and its application to power system optimization.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓	✓										
CO3	✓	✓										

CO4	✓	✓										
CO5	✓	✓			✓							

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1. S.S. Rao, "Engineering Optimization – Theory and Practice", John Wiley & Sons, Inc.,2009.
2. Hamdy A. Taha, Operations Research: An Introduction, 10th Edition, Pearson, 2016.
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PS5075 **SMART GRID**

L	**T**	**P**	**C**
3	**0**	**0**	**3**

COURSE OBJECTIVES

Students will be able to:

- Understand concept of smart grid and its advantages over conventional grid
- Know smart metering techniques
- Learn wide area measurement techniques
- Understanding the problems associated with integration of distributed generation & its solution through smart grid.
- To familiarize the high performance computing for Smart Gridapplications

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 HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATIONS 9

Local Area Network (LAN), House Area Network (HAN), Wide Area Network (WAN), Broadband over Power line (BPL), IP based Protocols, Computing algorithms for Smart grid, IOT, Cyber Security for Smart Grid.

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 advancedmetering infrastructure.

CO5:Develop more understanding on LAN, WAN and Cloud Computing for Smart Grid applications.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓				✓	✓	✓					
CO2	✓				✓	✓	✓					
CO3	✓				✓	✓	✓					
CO4	✓				✓	✓	✓					
CO5	✓				✓	✓	✓			✓		

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1. Stuart Borlase “Smart Grid :Infrastructure, Technology and Solutions”,CRC Press 2016.
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PS5076 **WIND ENERGY CONVERSION SYSTEM** **L T P C**
3 0 0 3

COURSE OBJECTIVES

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

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 FIXEDSPEEDSYSTEMS **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 VARIABLESPEED 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.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓		✓		✓							
CO3	✓		✓									
CO4	✓		✓		✓							
CO5	✓	✓	✓	✓								

REFERENCES

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3. Ion Boldea, "Variable speed generators", Taylor & Francis group,2006.
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HV5075 PRINCIPLES OF ELECTRIC POWER TRANSMISSION LT P C
3 0 0 3

COURSE OBJECTIVES:

- To understand power system structure and line configurations
- To compute line parameters and understand effect of ground return
- To understand voltage gradients of transmission line conductors.
- To compute electrostatic field and design of EHV AC
- To design and know basic concepts of HVDC lines.

UNIT I INTRODUCTION 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 – gradient factors and their use – distribution of voltage gradient on sub conductors of bundle - voltage gradients on conductors in the presence of ground wires on towers-I^2R loss and corona loss-RIV

UNIT IV 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, Design of EHV lines

UNIT V HVDC LINES 9

Introduction- Reliability and failure issues-Design-tower, ROW, clearances, insulators, electrical and mechanical protection-Maintenance-Control and protection-D.C Electric field and Magnetic field -Regulations and guide lines-under ground line design.

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1: Ability to identify voltage level and line configurations
CO2: Ability to model EHV AC and HVDC lines
CO3: Ability to compute voltage gradients of transmission line conductors
CO4: Ability to understand effects of electrostatic field on living and nonliving organisms
CO5: Ability to coordinate the insulation level of the power system

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓					✓	✓					
CO2	✓	✓			✓							
CO3	✓			✓	✓	✓	✓					
CO4						✓	✓					
CO5		✓	✓		✓	✓	✓					

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2. Pritindra Chowdhari, “Electromagnetic transients in Power System”, John Wiley and Sons Inc., 2009.
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HV5073 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY LT P C
3 0 0 3

COURSE OBJECTIVES:

- To provide fundamental knowledge on electromagnetic interference and electromagnetic compatibility.
- To know about the importance of Grounding and shielding.
- To study the important techniques to control EMI and EMC.
- To expose the knowledge on testing techniques as per Indian and international standards in EMI measurement.

UNIT I INTRODUCTION 9

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

UNIT II GROUNDING AND CABLING 9

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

UNIT III BALANCING, FILTERING AND SHIELDING 9

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

UNIT IV EMI IN ELEMENTS AND CIRCUITS 9

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

UNIT V ELECTROSTATIC DISCHARGE, STANDARDS AND TESTING TECHNIQUES 9

Static Generation- human body model- static discharges- ESD versus EMC, ESD protection in equipment- standards – FCC requirements – EMI measurements – Open area test site measurements and precautions- Radiated and conducted interference measurements, Control requirements and testing methods

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1 Ability to understand the types and sources of EMI.
CO2 Ability to understand the needs of rounding 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.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2		✓										
CO3			✓		✓		✓					
CO4			✓		✓							
CO5			✓		✓		✓					

REFERENCES

1. V.P. Kodali, “Engineering Electromagnetic Compatibility”, S. Chand, 1996.
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HV5072 DESIGN OF SUBSTATIONS L T P C
3 0 0 3

COURSE OBJECTIVES:

- To provide in-depth knowledge on design criteria of Air Insulated Substation (AIS) and Gas Insulated Substation (GIS).
- To obtain the knowledge about layout of AIS and GIS with proper Right of Way.
- To study the substation insulation co-ordination and protection scheme.
- To study the source and effect of fast transients in AIS and GIS.

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 wires and masts.

UNIT V FAST TRANSIENTS PHENOMENON IN AIS AND GIS 9

Introduction – Disconnector switching in relation to very fast transients – origin of VFTO – propagation and mechanism of VFTO – VFTO characteristics – Effects of VFTO.

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1 Ability to understand the fundamental components of **AIS AND GIS**.
CO2 Ability to understand the role of **major equipment and 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 **fast transients in Substation equipment.**

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2		✓										
CO3		✓	✓		✓	✓						
CO4				✓	✓	✓						
CO5			✓		✓	✓						

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.
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CO5071 ADVANCED NON-LINEAR CONTROL LT P C
3 0 0 3

COURSE OBJECTIVES

To educate the students on

- Theory of perturbation
- Gain scheduling and feedback linearization
- input-output stability and passivity
- theory and design of back stepping controllers.

UNIT I PERTURBATION THEORY 9

Vanishing and Non vanishing Perturbations – Continuity of solutions on the infinite interval – Interconnected systems – Slowly varying systems – Perturbation method – Averaging - Weakly

nonlinear second-order oscillators – Exercises

UNIT II SINGULAR PERTURBATIONS 9

Standard singular perturbation model – Time scale properties – Singular perturbation on the infinite interval – Slow and fast manifolds – stability analysis – exercises

UNIT III GAIN SCHEDULING AND FEEDBACK LINEARIZATION 9

Control problem – stabilization via linearization – integral control via linearization – gain scheduling – Input output linearization – Full state linearization – state feedback control – tracking- exercises

UNIT IV INPUT-OUTPUT STABILITY 9

L stability – L stability of state models – L_2 gain – feedback system: small gain theorem – exercises – Passivity – State models - L_2 and Lyapunov stability

UNIT V BAKSTEPPING CONTROL ALGORITHMS 9

Passivity based control – High gain observers – stabilization – Regulation via integral control - exercises

TOTAL : 45 PERIODS

COURSE OUTCOMES

CO1:Understanding different types of perturbation models.
CO2:Analysis of Stability of various perturbation models.
CO3:Apply gain schedule all kind of perturbation systems.
CO4:Apply L stability and lyapunov stability conditions for systems
CO5:Apply Bakstepping control algorithms.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓		✓	✓					
CO2	✓	✓	✓			✓	✓					
CO3	✓	✓	✓	✓	✓	✓	✓					
CO4	✓	✓	✓	✓		✓	✓					
CO5	✓	✓	✓	✓	✓	✓	✓					✓

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1. Hasan Khalil," Nonlinear systems and control", 3rd ed, PHI,
2. Slotine, J A E Slotine and W Li, "Applied Nonlinear control",1991, PHI
3. S.H. Zak," Systems and control", Oxford University Press

CO5251 **MACHINE LEARNING** **LT P C**
3 1 0 4

COURSE OBJECTIVES

To educate the students

- On several fundamental concepts and methods for machine learning.
- And get acquaint with basic learning algorithms and techniques and their applications.
- Acquire knowledge in processing, analyzing and handling data sets.
- Demonstrate typical applications of various clustering based learning algorithms

UNIT I INTRODUCTION TO MACHINE LEARNING 12

Objectives of machine learning – Human learning/ Machine learning – Types of Machinelearning:- Supervised Learning – Unsupervised learning – Reinforcement Learning –Evolutionary Learning - Regression – Classification – The Machine Learning Process:- DataCollection and Preparation – Feature Selection – Algorithm Choice – Parameter and Model Selection – Training – Evaluation.

UNIT II DATA PREPROCESSING 12

Data quality – Data preprocessing: - Data Cleaning:– Handling missing data and noisy data –Data integration:- Redundancy and correlation analysis – Data Reduction:- Dimensionalityreduction (Linear Discriminant Analysis – Principal Components Analysis – Factor Analysis –Independent Components Analysis) – Numerosity Reduction - Data Compression - Data Normalization and Data Discretization.

UNIT III SUPERVISED LEARNING 12

Linearly separable and nonlinearly separable populations – Multi Layer Perceptron –Back propagation Learning Algorithm – Radial Basis Function Network – Support VectorMachines: - Kernels – Risk and Loss Functions - Support Vector Machine Algorithm – Multi
Class Classification – Support Vector Regression.

UNIT IV CLUSTERING AND UNSUPERVISED LEARNING 12

Introduction – Clustering:- Partitioning Methods:- K-means algorithm - Hierarchical clustering –Fuzzy Clustering – Clustering High-Dimensional Data:- Problems – Challenges – Subspace Clustering – Biclustering - Self Organizing Map (SOM) - SOM algorithm.

UNIT V BAYESIAN LEARNING 12

Probability based clustering – The Expectation Maximization Algorithm – Bayesian Classification – Bayesian Networks – Learning Bayesian Networks – Hidden Markov Models.

TOTAL:60PERIODS

COURSE OUTCOMES:

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

CO1:To understand the basic theory underlying machine learning.
CO2:A range of machine learning algorithms along with their strengths and weaknesses.
CO3:To formulate machine learning problems corresponding to different applications.
CO4:To apply machine learning algorithms to solve problems of moderate complexity.
CO5:To read current research papers and understand the issues raised by current research.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1		✓		✓		✓						
CO2	✓	✓										
CO3	✓	✓			✓							✓
CO4	✓	✓				✓						✓
CO5	✓	✓		✓								✓

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2. Ian H. Witten, Eibe Frank, Mark A. Hall, Data Mining: Practical Machine Learning Tools and Techniques, Elsevier, 2011
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CO5075 **SYSTEM THEORY** **LT P C**
3 0 0 3

COURSE OBJECTIVES

- To educate on modeling and representing systems in state variable form.
- To educate on solving linear and non-linear state equations.
- To illustrate the role of controllability and observability.
- To educate on stability analysis of systems usig Lyapunov's theory.
- To educate on modal concepts and design of state and output feedback controllers and estimators.

UNIT I STATE VARIABLE REPRESENTATION 9

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

UNIT II SOLUTION OF STATE EQUATIONS 9

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

UNIT III CONTROLLABILITY AND OBSERVABILITY 9

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

UNIT IV STABILTY **9**

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

UNIT V MODAL CONTROL **9**

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

TOTAL : 45 PERIODS

COURSE OUTCOMES

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

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓								
CO2	✓	✓	✓	✓								
CO3	✓	✓	✓	✓								
CO4	✓	✓	✓	✓								
CO5	✓	✓	✓	✓								

REFERENCES:

1. M. Gopal, “Modern Control System Theory”, New Age International, 2005.
2. K. Ogatta, “Modern Control Engineering”, PHI, 2002.
3. John S. Bay, “Fundamentals of Linear State Space Systems”, McGraw-Hill, 1999.
4. D. Roy Choudhury, “Modern Control Systems”, New Age International, 2005.
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6. Z. Bubnicki, ”Modern Control Theory”, Springer, 2005.

CO5151	CONTROL SYSTEM DESIGN	L	T	P	C
		4	0	0	4

COURSE OBJECTIVES

To educate the students on

- Analysis and design of controllers for linear systems defined in transfer function and state space from.
- Application of optimal control and filtering concepts for linear systems continuous and discrete domain.

UNIT I ANALYSIS OF LINEAR SYSTEMS 12

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

UNIT II DESIGN OF SISO SYSTEM 12

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

UNIT III STATE SPACE DESIGN 12

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

UNIT IV OPTIMAL CONTROL 12

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

UNIT V OPTIMAL FILTERING 12

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

TOTAL: 60 PERIODS

COURSE OUTCOMES:

Ability to

CO1:Analyse controllers for linear systems defined in transfer function and state space forms.

CO2:Design controllers for linear systems defined in transfer function and state space forms.

CO3:Apply state space forms to continuous and discrete systems.

CO4:Apply optimal control to linear systems in continuous and discrete systems

CO5:Apply filtering concepts to linear systems in continuous and discrete systems.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓								
CO2	✓	✓	✓	✓								
CO3	✓	✓	✓	✓								
CO4	✓	✓	✓	✓								
CO5	✓	✓	✓	✓								

TEXT BOOKS:

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

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1. M.Gopal, Modern Control System Theory, 3rd edition, New Age International Publishers, 2014.
2. William S Levine, "Control System Fundamentals," The Control Handbook, CRC Press, Taylor and Francis Group, 2011.
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4. T. Glad and L. Ljung, "Control Theory –Multivariable and Non-Linear Methods", Taylor & Francis, 2002.

CO5073 OPTIMAL CONTROL AND FILTERING L T P C
3 0 0 3

COURSE OBJECTIVES

- To educate on formulation of optimal control problems and introduce the minimum principle.
- To educate on Linear Quadratic tracking problems- in continuous and discrete domain.
- To introduce the numerical techniques used for solving optimal control problems
- To educate on the concepts of filtering in the presence of noise.
- To educate on the theory and design of Kalman filter.

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 programming application for discrete and continuous systems.

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

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

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	✓	✓					
CO2	✓	✓	✓			✓	✓					
CO3	✓	✓	✓	✓		✓	✓					
CO4	✓	✓	✓	✓		✓	✓					
CO5	✓	✓	✓	✓	✓	✓	✓					✓

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.

CO5074 SYSTEM IDENTIFICATION AND ADAPTIVE CONTROL LT P C
3 0 0 3

COURSE OBJECTIVES

- To introduce various model structures for system identification.
- To impart knowledge on parametric and non-parametric identification
- To introduce non-linear identification techniques.
- To introduce the concept of adaptation techniques and control.
- To illustrate the identification and adaptive control techniques through case studies.

UNIT I MODELS FOR INDENTIFICATION 9

Models of LTI systems: Linear Models-State space Models-OE model- Model sets, Structures and Identifiability-Models for Time-varying and Non-linear systems: Models with Nonlinearities – Non-linear state-space models-Black box models, Fuzzy models'.

UNIT II NON-PARAMETRIC AND PARAMETRIC IDENTIFICATON 9

Transient response and Correlation Analysis – Frequency response analysis – Spectral Analysis – Least Square – Recursive Least Square –Forgetting factor- Maximum Likelihood – Instrumental Variable methods.

UNIT III NON-LINEAR IDENTIFICATION 9

Open and closed loop identification: Approaches – Direct and indirect identification – Joint input-output identification – Non-linear system identification – Wiener models – Power series expansions - State estimation techniques – Non linear identification using Neural Network and Fuzzy Logic.

UNIT IV ADAPTIVE COTROL AND ADAPTATION TECHNIQUES 9

Introduction – Uses – Auto tuning – Self Tuning Regulators (STR) – Model Reference Adaptive Control (MRAC) – Types of STR and MRAC – Different approaches to self-tuning regulators – Stochastic Adaptive control – Gain Scheduling.

UNIT V CASE STUDIES 9

Inverted Pendulum, Robot arm, process control application: heat exchanger, Distillation column, application to power system, Ship steering control.

TOTAL : 45 PERIODS

COURSE OUTCOMES

Ability to

CO1:model LTI system and to analyse the Non-linear state-space model of a black box.
CO2:analyse frequency, spectral, correlation and transient response of a system.
CO3:Identify the Open & closed Loop of a Non-linear system by Neural network and Fuzzy Logic controller.
CO4:Realize different tuning parameters for adaptive control and adaptive technique.
CO5:Apply different control techniques to various applications

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓									
CO2	✓	✓	✓									
CO3	✓	✓	✓	✓	✓							
CO4	✓	✓	✓	✓	✓							
CO5		✓	✓	✓	✓							

REFERENCES

1. Ljung," System Identification Theory for the User", PHI, 1987.
2. Torsten Soderstrom, Petre Stoica, "System Identification", prentice Hall 'International (UK) Ltd,1989.
3. Astrom and Wittenmark," Adaptive Control ", PHI
4. William S. Levine, " Control Hand Book".
5. Narendra and Annasamy," Stable Adaptive Control Systems, Prentice Hall, 1989.

PE5153 MODELLING AND DESIGN OF SMPS L T P C
3 0 0 3

COURSE OBJECTIVES:

- To perform steady state analysis of **Non-Isolated DC-DC** DC-DC converter.
- To perform steady state analysis of **Isolated** DC-DC converter.
- To understand different converter dynamics.
- To design controllers for DC DC converters.
- To design magnetics for SMPS applications.

UNIT I ANALYSIS OF NON-ISOLATED DC-DC CONVERTERS 9

Buck, Boost, Buck- Boost and Cuk converters: Principles of operation – Continuous conduction mode– Concepts of volt-sec balance and charge balance – Analysis and design based on steady-state relationships – Introduction to discontinuous conduction mode other topologies, SEPIC topologies - design examples.

UNIT II ANALYSIS OF ISOLATED DC-DC CONVERTERS 9

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

UNIT III CONVERTER DYNAMICS 9

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

UNIT IV CONTROLLER DESIGN 9

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

UNIT V DESIGN OF MAGNETICS 9

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

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1 Ability to design **Non-Isolated DC-DC**.
CO2 Ability to design **Isolated** DC-DC converter.
CO3 Ability to derive transfer function of different converters.
CO4 Ability to design controllers for DC DC converters.
CO5 Ability to design magnetics for SMPS applications

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓			✓		✓					
CO2	✓	✓			✓		✓					
CO3	✓	✓										
CO4	✓	✓		✓	✓		✓					
CO5	✓	✓		✓								

TEXT BOOKS:

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

REFERENCES:

1. John G. Kassakian, Martin F. Schlecht, George C. Verghese, “Principles of Power Electronics”, Pearson, India, New Delhi, 2010.
2. Simon Ang and Alejandra Oliva, “Power-Switching Converters”, CRC press, 3rd edition, 2011.
3. Philip T Krein, “ Elements of Power Electronics”, Oxford University Press, 2017.
4. Ned Mohan, “Power Electronics: A first course”, John Wiley,2012.
5. Issa Batarseh, Ahmad Harb, “Power Electronics- Circuit Analysis and Design, Second edition.

PE5252	VECTOR CONTROL OF AC MACHINES	L T P C 3 1 0 4

COURSE OBJECTIVES:

- To study the space phasor model of alternating current machines.
- To understand the field oriented control for permanent magnet synchronous machines.
- To analyse the concept of vector control based salient pole machines.
- To provide the knowledge about concept and control techniques of induction motor.
- To develop the flux oriented control circuit for induction motor.

UNIT I SPACE PHASOR MODEL OF AC MACHINES 12

Introduction-Smooth Air gap machine and salient pole machines- flux linkage space phasors- voltage equation- expression for electromagnetic torque.

UNIT II VECTOR CONTROL OF PM SYNCHRONOUS MACHINE 12

PMSM with surface mounted magnets- control scheme for of rotor oriented controlled PMSM with interior magnets-stator flux oriented control- rotor oriented control

UNIT III VECTOR CONTROL OF SALIENT POLE MACHINE WITH ELECTRICALLY EXCITED ROTOR 12

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

UNIT IV STATOR FLUX ORIENTED CONTROL OF INDUCTION MACHINE 12

Squirrel cage machine -Electromagnetic torque-voltage equations, doubly fed induction machines-control-static converter cascade, magnetizing flux oriented control of induction machine.

UNIT V ROTOR FLUX ORIENTED CONTROL OF INDUCTION MACHINE 12

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

TOTAL : 60 PERIODS

COURSE OUTCOMES:

CO1: Ability to carry out space phasor model for electrical machines.
CO2: Able to synthesis the vector controller for permanent magnet synchronous machines.
CO3: Able to compute and analyse the controllers of salient pole machines.
CO4: Able to understand and select the various control schemes suitable for induction motor.
CO5: The students acquire the flux oriented control concept of induction motor.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓		✓								✓	
CO2	✓	✓	✓	✓								
CO3	✓		✓									
CO4	✓	✓		✓								
CO5	✓		✓									

TEXT BOOKS:

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

REFERENCES:

1. Peter Vas, “Sensorless Vector and Torque Control”, Oxford University press, 1998.
2. PaulC.Krause, Oleg Wasyzczuk, Scott S, Sudhoff, “Analysis of Electric Machinery and Drive Systems”, John Wiley, Second Edition, 2010.

PE5074 POWER QUALITY LT P C
3 0 0 3

COURSE OBJECTIVES:

- To provide knowledge about various power quality issues.
- To understand the concept of power and power factor in single phase and three phase systems supplying nonlinear loads.
- To equip with required skills to design conventional compensation techniquesfor power factor correction and load voltage regulation.
- To introduce the control techniques for the active compensation.
- To understand mitigation techniques using custom power devices such as DVR & UPQC

UNIT I INTRODUCTION 9

Introduction – Characterisation 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 nonlinear load – three phase Balance system – three phase unbalanced system – three phase unbalanced and distorted source supplying non linear loads – concept of pf – three phase three wire – three phase four wire system.

UNIT III CONVENTIONAL LOAD COMPENSATION METHODS 9

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

UNIT IV LOAD COMPENSATION USING DSTATCOM 9

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

UNIT V SERIES COMPENSATION OF POWER DISTRIBUTION SYSTEM 9

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

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1 Ability to understand consequences of Power quality issues.
CO2 Ability to conduct harmonic analysis of single phase and three phase systems supplying nonlinear 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.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓										
CO2	✓	✓					✓					
CO3	✓	✓					✓					
CO4	✓	✓					✓					
CO5	✓	✓					✓					

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(2ndedition)

REFERENCES:

1. Power Quality - R.C.Duggan
2. Power system harmonics –A.J.Arrillga
3. Power Electronic Converter Harmonics –Derek A.Paice

PE5072 ADVANCED POWER CONVERTERS LT P C
3 0 0 3

COURSE OBJECTIVES:

- To study the operation of voltage lift circuits
- To study the operation of super lift circuits.
- To study the operation of ultra lift converters and multiple quadrant converters
- To study the principle of bidirectional dual active bridge converters
- To study the working principle of Impedance source converter.

UNIT I VOLTAGE-LIFT CONVERTERS 9

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

UNIT II POSITIVE OUTPUT &NEGATIVE OUTPUT SUPER-LIFT LUO-CONVERTERS 9

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

UNIT III ULTRA LIFT CONVERTERS AND MULTIPLE-QUADRANT OPERATING LUO-CONVERTERS 9

Ultra-Lift Luo- Converter- Operation - Continuous conduction and discontinuous conduction Mode and of Ultra-Lift Luo-Converter-Instantaneous Values- Multiple quadrant operating Luo Converters- Circuit explanations-modes of operation

UNIT IV BIDIRECTIONAL DUAL ACTIVE BRIDGE DC–DC CONVERTERS 9

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

UNIT V IMPEDANCE SOURCE CONVERTER 9

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

TOTAL : 45 PERIODS

COURSE OUTCOMES:

CO1Ability to understand the working of voltage lift circuits.
CO2 Ability to design super lift converters
CO3 Ability to design ultra-lift converters
CO4 Ability to understand the working and design of bi-directional DC-DC converters
CO5 Ability to understand the concepts related with impedance source converter

TEXT BOOKS:

1. Advanced DC/DC Converters,2nd Edition, Fang Lin Luo, Hong Ye, CRC press,2018
2. Impedance source power electronic converters, Yushan Liu , Haitham Abu-Rub , BaomingGe , Dr. Frede Blaabjerg , Omar Ellabban , Poh Chiang Loh, Wiley IEEE press, 2016.
3. High-Frequency Isolated Bidirectional Dual Active Bridge DC–DC Converters with Wide Voltage Gain, Deshang Sha,GuoXu, Springer 2019.

REFERENCES:

1. Essential DC/DC Converters, 1st Edition, Fang Lin Luo, Hong Ye, CRC,2005

2. Power Electronics Advanced Conversion Technologies, Second Edition, Fang Lin Luo, Hong Ye, 2018 CRC press.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	✓	✓					
CO2	✓	✓	✓	✓	✓	✓	✓				✓	
CO3	✓	✓	✓	✓	✓	✓	✓				✓	✓
CO4	✓	✓	✓	✓	✓	✓	✓				✓	✓
CO5	✓		✓	✓	✓	✓	✓				✓	✓

PE5152 ANALYSIS OF POWER CONVERTERS LT P C
3 1 0 4

COURSE OBJECTIVES:

- To provide the mathematical fundamentals necessary for deep understanding of power converter operating modes.
- To provide the electrical circuit concepts behind the different working modes of power converters so as to enable deep understanding of their operation.
- To provide required skills to formulate and design inverters for generic load and for machine loads.
- To equip with required skills to derive the criteria for the design of power converters starting from basic fundamentals.
- To analyze and comprehend the various operating modes of different configurations of power converters

UNIT I SINGLE PHASE AC-DC CONVERTER 12

Static Characteristics of power diode, SCR and GTO, half controlled and fully controlled converters with R-L, R-L-E loads and freewheeling diodes – continuous and discontinuous modes of operation - inverter operation –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 12

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 12

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 12

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 12

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 : 60 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

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓									✓
CO2	✓	✓	✓		✓							✓
CO3	✓	✓	✓		✓	✓	✓				✓	
CO4	✓	✓	✓		✓	✓	✓				✓	
CO5	✓	✓	✓		✓	✓					✓	✓

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.

PE5151	ANALYSIS OF ELECTRICAL MACHINES	L	T	P	C
		3	1	0	4

COURSE OBJECTIVES:

- To provide knowledge about the fundamentals of magnetic circuits, energy, force and torque of multi-excited systems.
- To analyze the steady state and dynamic state operation of DC machine through mathematical modeling and simulation in digital computer.
- To provide the knowledge of theory of transformation of three phase variables to two phase variables.
- To analyze the steady state and dynamic state operation of three-phase induction machines using transformation theory based mathematical modeling and digital computer simulation.
- To analyze the steady state and dynamic state operation of three-phase synchronous machines using transformation theory based mathematical modeling and digital computer simulation.

UNIT I PRINCIPLES OF ELECTRO MAGNETIC ENERGY CONVERSION 12

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

UNIT II DC MACHINES 12

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

UNIT III REFERENCE FRAME THEORY 12

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

UNIT IV INDUCTION MACHINES 12

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

UNIT V SYNCHRONOUS MACHINES 12

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

TOTAL : 60 PERIODS

COURSE OUTCOMES:

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

CO	PO											
	1	2	3	4	5	6	7	8	9	10	11	12
1	✓	✓	✓	✓	✓							
2	✓	✓	✓	✓	✓				✓	✓		
3	✓	✓	✓	✓	✓				✓	✓		
4	✓	✓	✓	✓	✓				✓	✓		
5	✓	✓	✓	✓	✓				✓	✓		

TEXT BOOKS:

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

REFERENCES:

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

PE5073 POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

- To provide knowledge about the stand alone and grid connected renewable energy systems.
- To equip with required skills to derive the criteria for the design of power converters for renewable energy applications.
- To analyse and comprehend the various operating modes of wind electrical generators and solar energy systems.
- To design different power converters namely AC to DC, DC to DC and AC to AC converters for renewable energy systems.
- To develop maximum power point tracking algorithms.

UNIT I INTRODUCTION **9**

Introduction to renewable energy systems, environmental aspects of electric energy conversion, impacts of renewable energy generation on environment, GHG Effect, Qualitative study of different renewable energy resources Ocean, Biomass, Hydrogen energy systems and Fuel cells.

UNIT II POWER ELECTRONIC CONVERTERS FOR RENEWABLE ENERGY 9

Solar: Block diagram of solar photo voltaic system: line commutated converters (inversion mode) - Boost and buck-boost converters.
Wind: three phase AC voltage controllers- AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid Interactive Inverters-matrix converters.

UNIT III PHOTO VOLTAIC ENERGY CONVERSION SYSTEMS 9

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

UNIT IV WIND ENERGY CONVERSION SYSTEMS 9

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

UNIT V HYBRID RENEWABLE ENERGY SYSTEMS AND MPPT 9

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

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1 Ability to understand different renewable energy systems
CO2 Ability to design and simulate power electronics converters used for interfacing Renewable energy systems
CO3 Ability to design standalone renewable energy system employing embedded energy storage and MPPT strategy.
CO4 Ability to design grid connected renewable energy system.
CO5 Ability to extract maximum power using different MPPT algorithms

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1						✓	✓	✓			✓	
CO2	✓	✓	✓	✓								
CO3	✓	✓	✓	✓					✓			
CO4	✓	✓	✓	✓								
CO5	✓	✓	✓	✓								

TEXTBOOKS:

1. S.N.Bhadra, D. Kastha, & S. Banerjee “Wind Electrical Systems”, Oxford University Press, 2009.
2. Haitham Abu-Rub, Mariusz Malinowski and Kamal Al-Haddad, “Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications”, IEEE Press and John Wiley & Sons Ltd Press, 2014.

REFERENCES:

1. Rashid .M. H “power electronics Hand book”, Academic press, 2001.
2. Rai. G.D, “Non-conventional energy sources”, Khanna publishes, 1993.

3. Rai. G.D," Solar energy utilization", Khanna publishes, 1993.
4. Gray, L. Johnson, "Wind energy system", prentice hall linc, 1995.
5. Non-conventional Energy sources B.H.Khan Tata McGraw-hill Publishing Company, New Delhi.

PW5071 ELECTRIC VEHICLES AND POWER MANAGEMENT LT P C
3 0 0 3

COURSE OBJECTIVES:

- To provide knowledge about electric vehicle architecture and power train components.
- To know the concepts of dynamics of electrical vehicles
- To impart knowledge on vehicle control for standard drive cycles of hybrid electrical vehicles (HEVs)
- To understand the concept of energy storage systems.
- To provide knowledge about different energy sources and energy management in HEVs.

UNIT I HYBRID ELECTRIC VEHICLE ARCHITECTURE AND POWER TRAIN COMPONENTS 9

History of evolution of Electric Vehicles - 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 and 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, models, 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:

CO1: Learned the electric vehicle architecture and power train components.
CO2: Acquired the concepts of dynamics of electrical vehicles
CO3: Able to understand the vehicle control for standard drive cycles of hybrid electrical vehicles (HEVs).
CO4: Ability to design and select energy storage systems.
CO5: Acquired the knowledge of different energy sources and energy management in HEVs.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓			✓							
CO2	✓	✓	✓						✓			
CO3	✓			✓		✓	✓					
CO4	✓	✓	✓		✓							
CO5	✓		✓								✓	

REFERENCES:

1. Iqbal Husain, 'Electric and Hybrid Electric Vehicles', 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.

PW5074 ENERGY STORAGE TECHNOLOGIES LT P C
3 0 0 3

COURSE OBJECTIVES:

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

UNIT I INTRODUCTION 9

Necessity of energy storage – types of energy storage – comparison of energy storage technologies – Applications.

UNIT II THERMAL STORAGE SYSTEM 9

Thermal storage – Types – Modeling of thermal storage units – Simple water and rock bed storage system – pressurized water storage system – Modelling of phase change storage system – Simple units, packed bed storage units - Modelling using porous medium approach, Use of TRNSYS.

UNIT III ELECTRICAL ENERGY STORAGE 9

Fundamental concept of batteries – measuring of battery performance, charging and is charging of a battery, storage density, energy density, and safety issues. Types of batteries – Lead Acid, ickel – Cadmium, Zinc Manganese dioxide - Mathematical Modelling for Lead Acid Batteries – Flow Batteries.

UNIT IV FUEL CELL 9

Fuel Cell – History of Fuel cell, Principles of Electrochemical storage – Types – Hydrogen oxygen cells, Hydrogen air cell, Hydrocarbon air cell, alkaline fuel cell, detailed analysis – advantages and disadvantages –Fuel Cell Thermodynamics.

UNIT V ALTERNATE ENERGY STORAGE TECHNOLOGIES 9

Flywheel , Super capacitors, Principles & Methods – Applications, Compressed air Energy storage, Concept of Hybrid Storage – Applications, Pumped Hydro Storage – Applications.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Gained knowledge of various storage technologies.
CO2: Able to design a thermal storage system.
CO3: Ability to model battery storage system.
CO4: Learned to analyze the thermodynamics of fuel cell.
CO5: Gained Knowledge of various applications of storage technologies and perform the selection based on techno-economic view point.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓										
CO2			✓									
CO3			✓									
CO4			✓									
CO5	✓		✓									

REFERENCES

1. Ibrahim Dincer and Mark A. Rosen, 'Thermal Energy Storage Systems and Applications', JohnWiley & Sons 2002.
2. James Larminie and Andrew Dicks, 'Fuel cell systems Explained', Wiley publications, 2003.
3. Lunardini.V.J, 'Heat Transfer in Cold Climates', John Wiley and Sons 1981.
4. Ru-shiliu, Leizhang and Xueliang sun, 'Electrochemical technologies for energy storage and conversion', Wiley publications, 2012.
5. Schmidt.F.W. and Willmott.A.J., 'Thermal Storage and Regeneration', Hemisphere Publishing Corporation, 1981.

PW5075 GRID INTEGRATION OF RENEWABLE ENERGY SOURCES LT P C
3 0 0 3

COURSE OBJECTIVES:

- To study about the integration of various renewable energy sources into the grid.
- To analyse various grid issues due to renewable energy sources.
- To analyse the dynamics of network due to wind farm
- To provide knowledge about power system stabilizers.
- To provide knowledge about grid connected and standalone PV system

UNIT I INTRODUCTION 9

Introduction to renewable energy grid integration - Concept of mini/micro 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 - Network voltage management - Power quality management (voltage dips, harmonics, flickers, and reactive power control) - Frequency management - Influence of WECS on system transient response - Interconnection standards and grid code requirements for integration.

UNIT II NETWORK INFLUENCE OF GENERATION TYPE 9

starting – Network voltage management – Thermal/Active power management – Network power quality management – Transient system performance – Fault level issues – Protection.

UNIT III INFLUENCE OF WIND FARMS ON NETWORK DYNAMIC PERFORMANCE 9

Dynamic Stability and its Assessment – Dynamic characteristics of Synchronous Generation - A Synchronizing power and Damping power model of a Synchronous Generator – Influence of Automatic Voltage Regulator on Damping – Influence on Damping of Generator Operating Conditions – Influence of Turbine Governor on Generator Operation – Transient Stability – Voltage Stability – Influence of Generation Type on Network Dynamic Stability – Dynamic Interaction of Wind Farms with the Network – influence of Wind Generation on Network Transient Performance.

UNIT IV POWER SYSTEM STABILIZERS AND NETWORK DAMPING CAPABILITY OF WIND 9

A Power System Stabilizer for a Synchronous Generator - A Power System Stabilizer for a DFIG - A Power System Stabilizer for a FRC Wind Farm.

UNIT V STAND ALONE AND GRID CONNECTED PV SYSTEM 9

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

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Know about the integration of various renewable energy sources into the grid.
CO2: Able to analyze various grid issues due to renewable energy sources.
CO3: Able to analyze the dynamics of network due to windfarm
CO4: Know about power system stabilizers.
CO5: Able to design the grid connected and standalone PV system.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2		✓										
CO3		✓										
CO4		✓										
CO5			✓									

REFERENCES

1. Stuart R.Wenham, Martin A. Green, Muriel E. Watt and Richard Corkish, 'Applied Photovoltaics', Earthscan, UK, 2007.
2. Joshua Earnest, 'Wind power technology', II Edition, PHI, 2015.
3. Olimpo Anaya-Lara, Nick Jenkins, Janaka Ekanayake, Phill Cartwright and Mike Hughes, 'WIND GENERATIONModelling and Control', A John Wiley and Sons, Ltd., Publication, 2009.
4. Brenden Fox, Damian Flynn and Leslie Bryans, 'Wind Power Integration Connection and system operational aspects', Published by The Institute of Engineering and Technology, London, United Kingdom, 2007.
5. Frank S. Barnes & Jonah G.Levine, 'Large Energy Storage Systems Handbook', CRC Press, 2011.
6. S.P. Sukhatme, 'Solar Energy', Tata McGraw Hill, 1987.
7. Chetan Singh Solanki, 'Solar Photovoltaic Technology and Systems' – A Manual for Technicians, Trainees and Engineers, PHI, 2014.

PW5076 MICRO-GRID OPERATION AND CONTROL LT P C
3 0 0 3

COURSE OBJECTIVES:

- To illustrate the concept of micro sources and storage.
- To study concept of AC microgrid and its controllers.
- To study concept of DC microgrid and its controllers.
- To study concept of hybrid microgrid and its controllers.
- To study concept of islanding and impact on protection.

UNIT I MICRO SOURCES AND STORAGE 9

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

UNIT II 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 III 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 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:

CO1: Ability to analyze micro-sources and storage systems.
CO2: Able to analyse the configurations and control aspects of AC microgrid.
CO3: Understand and analyse the configurations and control aspects of DC microgrid.
CO4: Acquired knowledge about configurations and control aspects of Hybrid microgrid.
CO5: Learned the protection aspects of microgrid.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓						✓					
CO2	✓	✓	✓	✓	✓		✓					
CO3	✓	✓	✓	✓	✓		✓					
CO4	✓	✓	✓	✓	✓		✓					
CO5	✓		✓	✓								

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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. FarzamNejabatkhah and Yun Wei Li, 'Overview of Power Management Strategies of Hybrid AC/DC Microgrid', IEEE Transactions on Power Electronics, 2014.

PW5077 RENEWABLE ENERGY TECHNOLOGY LT P C
3 0 0 3

COURSE OBJECTIVES

- To Provide knowledge about various renewable energy technologies
- To enable students to understand and design a PV system.
- To provide knowledge about wind energy system.
- To Provide knowledge about various possible hybrid energy systems
- To gain knowledge about application of various renewable energy technologies

UNIT I INTRODUCTION 9

Primary energy sources, renewable vs. non-renewable primary energy sources, renewable energy resources in India, Current usage of renewable energy sources in India, future potential of renewable energy in power production and development of renewable energy technologies.

UNITII SOLAR ENERGY 9

Solar Radiation and its measurements, Solar Thermal Energy Conversion from plate Solar Collectors, Concentrating Collectors and its Types , Efficiency and performance of collectors, Applications of Solar Thermal Energy use of low and medium, high temperature and recent advances in industry and buildings. Direct Solar Electricity Conversion from Photovoltaic, types of solar cells and its application of battery charger, domestic lighting, street lighting, and water pumping, power generation schemes. Recent Advances in PV Applications: Building Integrated PV, Grid Connected PV Systems, Hybrid Systems and Solar Cars, Solar Energy Storage system and their economic aspects.

UNIT III WIND ENERGY 9

Wind energy principles, wind site and its resource assessment, wind assessment, Factors influencing wind, wind turbine components, wind energy conversion systems (WECS), Classification of WECS devices, wind electric generating and control systems, characteristics and applications. Hybrid systems - safety and environmental aspects, economic aspects.

UNIT IV BIO-ENERGY 9

Energy from biomass, Principle of biomass conversion technologies/process and their classification, Bio gas generation, types of biogas plants, selection of site for biogas plant, classification of biogas plants, Advantage and disadvantages of biogas generation, thermal gasification of biomass, biomass gasifies, Application of biomass and biogas plants and their economics.

UNIT V OTHER TYPES OF ENERGY 9

Energy conversion from Hydrogen and Fuel cells, Geo thermal energy Resources, types of wells,

methods of harnessing the energy, potential in India. OTEC, Principles utilization, setting of OTEC plants, thermodynamic cycles. Tidal and wave energy: Potential and conversion techniques, mini-hydel power plants and their economics.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Attained knowledge about various renewable energy technologies
CO2: Ability to understand and design a PV system.
CO3: Understand the concept of various wind energy system.
CO4: Gained knowledge about various possible hybrid energy systems
CO5: Attained knowledge about various application of renewable energy technologies

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓		✓									
CO3	✓		✓									
CO4	✓		✓									
CO5			✓									

REFERENCES

1. Twidell & Wier,**'**Renewable Energy Resources' CRC Press(Taylor & Francis).
2. Tiwari and Ghosal/ Narosa,'Renewable energy resources'.
3. D.P.Kothari,K.C.Singhal,'Renewable energy sources and emerging technologies', P.H.I.
4. D.S.Chauhan, S.K. Srivastava, 'Non – Conventional Energy Resources', New Age Publishers, 2006.
5. B.H.Khan, 'Non – Conventional Energy Resources', Tata Mc Graw Hill, 2006.

PW5078 SCADA SYSTEM AND APPLICATIONS MANAGEMENT L T P C

3 0 0 3

COURSE OBJECTIVES:

- To understand the basic concepts and components of SCADA
- To introduce the SCADA communication protocols
- To apply the SCADA technology to power systems for automation
- To provide knowledge about SCADA based energy management centre.
- To emphasis the role of SCADA monitoring and control concepts.

UNIT I INTRODUCTION TO SCADA 9

SCADA overview, general features, SCADA architecture, SCADA Applications, Benefits, Remote Terminal Unit (RTU), Human- Machine Interface Units (HMI), Display Monitors/Data Logger Systems, Intelligent Electronic Devices (IED), Communication Network, SCADA Server, SCADA Control systems and Control panels

UNIT II SCADA COMMUNICATION 9

SCADA Communication requirements, Communication protocols: Past, Present and Future, Structure of a SCADA Communications Protocol, Comparison of various communication protocols, IEC61850 based communication architecture, Communication media like Fiber optic, PLCC etc. Interface provisions and communication extensions, synchronization with NCC, DCC, IOT, Cyber cell, Redundancy of Network.

UNIT III SCADA IN POWER SYSTEM AUTOMATION 9

Applications in Generation, Transmission and Distribution sector, Substation SCADA system Functional description, System specification, System selection such as Substation configuration, IEC61850 ring configuration, SAS cubicle concepts, gateway interoperability list, signal naming concept. System Installation, Testing and Commissioning,

CASE STUDIES:SCADA Design for 66/11KV and 132/66/11KV or 132/66 KV any utility Substation and IEC 61850 based SCADA Implementation issues in utility Substations

UNIT IV ENERGY MANAGEMENT CENTRE 9

Functions, production control and load management, economic despatch, distributed centres and power pool management, energy management system and its role.

UNIT V SCADA MONITORING AND CONTROL 9

Online monitoring the event and alarm system, trends and reports, Blocking list, Event disturbance recording. Control function: Station control, bay control, breaker control and disconnector control.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Students will learn the SCADA system components and its significance.
CO2: Students will understand the need and advantages of communication protocols for SCADA
CO3: Students will get implementation knowledge about the application of SCADA to Power System.
CO4: Students will get exposure to the best operating mechanism for Energy centre based on SCADA concepts
CO5: Students will understand the need and importance of monitoring and control logic for SCADA based power systems.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓				✓							✓
CO2			✓		✓							
CO3		✓	✓		✓				✓			✓
CO4		✓	✓		✓				✓			✓
CO5	✓		✓									

REFERENCES:

1. Stuart A. Boyer, 'SCADA-Supervisory Control and Data Acquisition', Instrument Society of America Publications,USA,2004.
2. Gordon Clarke, Deon Reynders, 'Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems', Newnes Publications, Oxford, UK,2004.
3. William T. Shaw, 'Cybersecurity for SCADA systems', PennWell Books, 2006.
4. David Bailey, Edwin Wright, 'Practical SCADA for industry', Newnes, 2003.
5. Michael Wiebe, 'A guide to utility automation: AMR, SCADA, and IT systems for electric Power', PennWell, 1999.
6. Dieter K. Hammer, Lonnie R. Welch, Dieter K. Hammer, 'Engineering of Distributed Control Systems', Nova Science Publishers, USA, 1st Edition, 2001.

ET5071 ADVANCED DIGITAL SIGNAL PROCESSING LT P C
3 0 0 3

COURSE OBJECTIVES:

- To expose the fundamentals of digital signal processing in frequency domain& its application
- To teach the fundamentals of digital signal processing in time-frequency domain& its application
- To teach the fundamentals of audio signal processing & its application
- To discuss on Application development with commercial family of DS Processors
- To involve Discussions/ Practice/Exercise onto revising & familiarizing the concepts acquired over the 5 Units of the subject for improved employability skills

UNIT I INTRODUCTION TO DIGITAL SIGNAL PROCESSING 6

Introduction to Digital Signal Processing System- Discrete Time Sequences- Time-Invariant & Time-variant Systems, Decimation and Interpolation- The Sampling Process - Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT)- Basics of Digital Filters- FIR Filters, IIR Filters -adaptive filter based on LMS.

UNIT II WAVELET TRANSFORM 9

Introduction to continuous wavelet transform- discrete wavelet transform -orthogonal wavelet decomposition- Multiresolution Analysis-Wavelet function-DWT, bases, orthogonal Basis-Scaling function, Wavelet coefficients- Multirate signal processing and their relationship to filter banks-Digital filtering interpolation(i) Decomposition filters, (ii) reconstruction, the signal- Example MRA-Haar & Daubechies wavelet.

UNIT III AUDIO SIGNAL PROCESSING 12

Introduction to Speech and Audio Processing - Speech Signal Processing- Pitch-period estimation, all-pole and all-zero filters- convolution - autoregressive model, autocorrelation estimation, General structure of speech coders; Requirements of speech codecs –quality, LPC model of speech production- LPC encoders and decoders-Power spectral density, periodogram ,Spectral measures of audio signal.

UNIT IV ARCHITECTURES OF COMMERCIAL DIGITAL SIGNAL PROCESSORS 12

Introduction, catogorisation of DSP Processors-one case example Architecture Processor for Fixed Point (Blackfin),Floating Point & Speech Processor- Basics of Architecture – study of functional variations of Computational building blocks(with comparison onto their MAC, Bus Architecture ,I/O interface,application).

UNIT V IMPLEMENTATION OF DSP BASED SYSTEMS 6

Introduction- Interfacing processor- Memory Interface-I/O Interface-Mapping of DSP algorithm onto hardware -Design of Filter-FFT Algorithm- Application with DSP based Interfacing- Power Meter; DSP as motor control

NOTE: Discussions/Miniproject/Practice on Workbench : Signal analysis transforms, Filter design concepts with simulation tools as Matlab /Labview/ VLSI/CCS/other suites to understand the commercial DSP processor technology and practice in programming.

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TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: The concepts of Time and frequency analysis of Signal Transforms based on signal types.
CO2: The fundamentals of Time-Frequency Transforms are introduced
CO3: Analyze the quality and properties of speech based on DSP
CO4: Study features through comparison on commercial available DSProcessors
CO5: Improved Employability and entrepreneurship capacity due to knowledge up gradation on recent trends in signal processing for embedded systems design.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓							
CO2		✓	✓									
CO3		✓	✓									
CO4		✓	✓									
CO5		✓			✓							

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1. John G. Proaks, Dimitris G. Manolakis, “Digital Signal Processing”, Pearson Education 2002.
2. Vinay K.Ingle,John G.Proakis,”DSP-A Matlab Based Approach”,Cengage Learning,2010
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4. Sen M.Kuo and Woon-Seng S.Gan, Digital Signal Processors-Architectures, implementation and applications”, Pearson Education 2008.
5. Avatar Sing, S. Srinivasan, “Digital Signal Processing- Implementation using DSP Microprocessors with Examples from TMS320C54xx”, Thomson India,2004.
6. Ashok Ambardar,”Digital Signal Processing: A Modern Introduction”,Thomson India edition, 2007.
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8. Raghuveer M.Rao and Ajit S. Bapardikar, Wavelet transforms- Introduction to theory and applications, Pearson Education, 2000.
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11. B Venkataramani and M Bhaskar **“**Digital Signal Processors**”**, TMH, 2nd, 2010
12. “Digital Speech” by A.M.Kondoz, Second Edition (Wiley Students_ Edition), 2004.

OPEN ELECTIVE COURSES (OEC)

OE5091 BUSINESS DATA ANALYTICS L T P C
3 0 0 3

OBJECTIVES:

- To understand the basics of business analytics and its life cycle.
- To gain knowledge about fundamental business analytics.
- To learn modeling for uncertainty and statistical inference.
- To understand analytics using Hadoop and Map Reduce frameworks.
- To acquire insight on other analytical frameworks.

UNIT I OVERVIEW OF BUSINESS ANALYTICS 9

Introduction – Drivers for Business Analytics – Applications of Business Analytics: Marketing and Sales, Human Resource, Healthcare, Product Design, Service Design, Customer Service and Support – Skills Required for a Business Analyst – Framework for Business Analytics Life Cycle for Business Analytics Process.

Suggested Activities:

- Case studies on applications involving business analytics.
- Converting real time decision making problems into hypothesis.
- Group discussion on entrepreneurial opportunities in Business Analytics.

Suggested Evaluation Methods:

- Assignment on business scenario and business analytical life cycle process.
- Group presentation on big data applications with societal need.
- Quiz on case studies.

UNIT II ESSENTIALS OF BUSINESS ANALYTICS 9

Descriptive Statistics – Using Data – Types of Data – Data Distribution Metrics: Frequency, Mean, Median, Mode, Range, Variance, Standard Deviation, Percentile, Quartile, z-Score, Covariance, Correlation – Data Visualization: Tables, Charts, Line Charts, Bar and Column Chart, Bubble Chart, Heat Map – Data Dashboards.

Suggested Activities:

- Solve numerical problems on basic statistics.
- Explore chart wizard in MS Excel Case using sample real time data for data visualization.
- Use R tool for data visualization.

Suggested Evaluation Methods:

- Assignment on descriptive analytics using benchmark data.
- Quiz on data visualization for univariate, bivariate data.

UNIT III MODELING UNCERTAINTY AND STATISTICAL INFERENCE 9

Modeling Uncertainty: Events and Probabilities – Conditional Probability – Random Variables – Discrete Probability Distributions – Continuous Probability Distribution – Statistical Inference: Data Sampling – Selecting a Sample – Point Estimation – Sampling Distributions – Interval Estimation – Hypothesis Testing.

Suggested Activities:

- Solving numerical problems in sampling, probability, probability distributions and hypothesis testing.
- Converting real time decision making problems into hypothesis.

Suggested Evaluation Methods:

- Assignments on hypothesis testing.
- Group presentation on real time applications involving data sampling and hypothesis testing.
- Quizzes on topics like sampling and probability.

UNIT IV ANALYTICS USING HADOOP AND MAPREDUCE FRAMEWORK 9

Introducing Hadoop– RDBMS versus Hadoop–Hadoop Overview – HDFS (Hadoop Distributed File System) – Processing Data with Hadoop– Introduction to MapReduce – Features of MapReduce – Algorithms Using Map-Reduce: Matrix-Vector Multiplication, Relational Algebra Operations, Grouping and Aggregation – Extensions to MapReduce.

Suggested Activities:

- Practical – Install and configure Hadoop.
- Practical – Use web based tools to monitor Hadoop setup.
- Practical – Design and develop MapReduce tasks for word count, searching involving text corpus etc.

Suggested Evaluation Methods:

- Evaluation of the practical implementations.
- Quizzes on topics like HDFS and extensions to MapReduce.

UNIT V OTHER DATA ANALYTICAL FRAMEWORKS 9

Overview of Application development Languages for Hadoop – PigLatin – Hive – Hive Query Language (HQL) – Introduction to Pentaho, JAQL – Introduction to Apache: Sqoop, Drill and Spark, Cloudera Impala – Introduction to NoSQL Databases – Hbase and MongoDB.

Suggested Activities:

- Practical – Installation of NoSQL database like MongoDB.
- Practical – Demonstration on Sharding in MongoDB.
- Practical – Install and run Pig
- Practical – Write PigLatin scripts to sort, group, join, project, and filter data.
- Design and develop algorithms to be executed in MapReduce involving numerical methods for analytics.

Suggested Evaluation Methods:

- Mini Project (Group) – Real time data collection, saving in NoSQL, implement analytical techniques using Map-Reduce Tasks and Result Projection.

TOTAL: 45 PERIODS

OUTCOMES:

On completion of the course, the student will be able to:

- Identify the real world business problems and model with analytical solutions.
- Solve analytical problem with relevant mathematics background knowledge.
- Convert any real world decision making problem to hypothesis and apply suitable statistical testing.
- Write and Demonstrate simple applications involving analytics using Hadoop and MapReduce

- Use open source frameworks for modeling and storing data.
- Apply suitable visualization technique using R for visualizing voluminous data.

REFERENCES:

1. VigneshPrajapati, “Big Data Analytics with R and Hadoop”, Packt Publishing, 2013.
2. Umesh R Hodeghatta, UmeshaNayak, “Business Analytics Using R – A Practical Approach”, Apress, 2017.
3. AnandRajaraman, Jeffrey David Ullman, “Mining of Massive Datasets”, Cambridge University Press, 2012.
4. Jeffrey D. Camm, James J. Cochran, Michael J. Fry, Jeffrey W. Ohlmann, David R. Anderson, “Essentials of Business Analytics”, Cengage Learning, second Edition, 2016.
5. U. Dinesh Kumar, “Business Analytics: The Science of Data-Driven Decision Making”, Wiley, 2017.
6. A. Ohri, “R for Business Analytics”, Springer, 2012
7. Rui Miguel Forte, “Mastering Predictive Analytics with R”, Packt Publication, 2015.

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	1	2	3	1
CO2	2	1	1	2	1	1
CO3	1	1	2	3	3	1
CO4	2	2	1	2	1	1
CO5	1	1	2	2	1	1
CO6	1	1	1	3	2	1

OE5092 INDUSTRIAL SAFETY LT P C
3 0 0 3

OBJECTIVES:

- Summarize basics of industrial safety
- Describe fundamentals of maintenance engineering
- Explain wear and corrosion
- Illustrate fault tracing
- Identify preventive and periodic maintenance

UNIT I INTRODUCTION 9

Accident, causes, types, results and control, mechanical and electrical hazards, types, causes and preventive steps/procedure, describe salient points of factories act 1948 for health and safety, wash rooms, drinking water layouts, light, cleanliness, fire, guarding, pressure vessels, etc, Safety color codes. Fire prevention and firefighting, equipment and methods.

UNIT II FUNDAMENTALS OF MAINTENANCE ENGINEERING 9

Definition and aim of maintenance engineering, Primary and secondary functions and responsibility of maintenance department, Types of maintenance, Types and applications of tools used for maintenance, Maintenance cost & its relation with replacement economy, Service life of equipment.

UNIT III WEAR AND CORROSION AND THEIR PREVENTION 9

Wear- types, causes, effects, wear reduction methods, lubricants-types and applications, Lubrication methods, general sketch, working and applications, i. Screw down grease cup, ii. Pressure grease gun, iii. Splash lubrication, iv. Gravity lubrication, v. Wick feed lubrication vi. Side feed lubrication, vii. Ring lubrication, Definition, principle and factors affecting the corrosion. Types of corrosion, corrosion prevention methods.

UNIT IV FAULT TRACING 9

Fault tracing-concept and importance, decision tree concept, need and applications, sequence of fault finding activities, show as decision tree, draw decision tree for problems in machine tools, hydraulic, pneumatic, automotive, thermal and electrical equipment's like, I. Any one machine tool, ii. Pump iii. Air compressor, iv. Internal combustion engine, v. Boiler, vi. Electrical motors, Types of faults in machine tools and their general causes.

UNIT V PERIODIC AND PREVENTIVE MAINTENANCE 9

Periodic inspection-concept and need, degreasing, cleaning and repairing schemes, overhauling of mechanical components, overhauling of electrical motor, common troubles and remedies of electric motor, repair complexities and its use, definition, need, steps and advantages of preventive maintenance. Steps/procedure for periodic and preventive maintenance of: I. Machine tools, ii. Pumps, iii. Air compressors, iv. Diesel generating (DG) sets, Program and schedule of preventive maintenance of mechanical and electrical equipment, advantages of preventive maintenance. Repair cycle concept and importance

TOTAL: 45 PERIODS

OUTCOMES:

CO1: Ability to summarize basics of industrial safety
CO2: Ability to describe fundamentals of maintenance engineering
CO3: Ability to explain wear and corrosion
CO4: Ability to illustrate fault tracing
CO5: Ability to identify preventive and periodic maintenance

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓											
CO3	✓	✓	✓									
CO4	✓	✓	✓									
CO5	✓	✓	✓									

REFERENCES:

1. Audels, Pump-hydraulic Compressors, Mcgrew Hill Publication, 1978.
2. Garg H P,Maintenance Engineering, S. Chand and Company,1987.
3. Hans F. Winterkorn ,Foundation Engineering Handbook, Chapman & Hall London,2013.
4. Higgins & Morrow , Maintenance Engineering Handbook, Eighth Edition,2008

OE5093 OPERATIONS RESEARCH LT P C
3 0 0 3

OBJECTIVES:

- Solve linear programming problem and solve using graphical method.
- Solve LPP using simplex method
- Solve transportation , assignment problems

- Solve project management problems
- Solve scheduling problems

UNIT I LINEAR PROGRAMMING 9

Introduction to Operations Research – assumptions of linear programming problems - Formulations of linear programming problem – Graphical method

UNIT II ADVANCES IN LINEAR PROGRAMMING 9

Solutions to LPP using simplex algorithm- Revised simplex method - primal dual relationships – Dual simplex algorithm - Sensitivity analysis

UNIT III NETWORK ANALYSIS – I 9

Transportation problems -Northwest corner rule, least cost method,Voges's approximation method - Assignment problem -Hungarian algorithm

UNIT IV NETWORK ANALYSIS – II 9

Shortest path problem: Dijkstra's algorithms, Floyds algorithm, systematic method -CPM/PERT

UNIT V NETWORK ANALYSIS – III 9

Scheduling and sequencing - single server and multiple server models - deterministic inventory models - Probabilistic inventory control models

TOTAL: 45 PERIODS

OUTCOMES:

CO1: To formulate linear programming problem and solve using graphical method.
CO2: To solve LPP using simplex method
CO3: To formulate and solve transportation, assignment problems
CO4: To solve project management problems
CO5: To solve scheduling problems

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓											
CO3	✓	✓	✓									
CO4	✓	✓	✓									
CO5	✓	✓	✓									

REFERENCES:

1. Harvey M Wagner, Principles of Operations Research: Prentice Hall of India 2010
2. Hitler Libermann, Operations Research: McGraw Hill Pub. 2009
3. Pant J C, Introduction to Optimisation: Operations Research, Jain Brothers, Delhi, 2008
4. Pannerselvam, Operations Research: Prentice Hall of India 2010
5. Taha H A, Operations Research, An Introduction, PHI, 2008

OE5094 COST MANAGEMENTOF ENGINEERING PROJECTS L T P C
3 0 0 3

OBJECTIVES:

- Summarize the costing concepts and their role in decision making
- Infer the project management concepts and their various aspects in selection
- Interpret costing concepts with project execution

- Develop knowledge of costing techniques in service sector and various budgetary control techniques
- Illustrate with quantitative techniques in cost management

UNIT I INTRODUCTION TO COSTING *CONCEPTS* 9

Objectives of a Costing System; Cost concepts in decision-making; Relevant cost, Differential cost, Incremental cost and Opportunity cost; Creation of a Database for operational control.

UNIT II INTRODUCTION TO PROJECT MANAGEMENT 9

Project: meaning, Different types, why to manage, cost overruns centres, various stages of project execution: conception to commissioning. Project execution as conglomeration of technical and nontechnical activities, Detailed Engineering activities, Pre project execution main clearances and documents, Project team: Role of each member,Importance Project site: Data required with significance, Project contracts.

UNIT III PROJECT EXECUTION AND COSTING CONCEPTS 9

Project execution Project cost control, Bar charts and Network diagram, Project commissioning: mechanical and process, Cost Behavior and Profit Planning Marginal Costing; Distinction between Marginal Costing and Absorption Costing; Break-even Analysis, Cost-Volume-Profit Analysis, Various decision-making problems, Pricing strategies: Pareto Analysis, Target costing, Life Cycle Costing.

UNIT IV COSTING OF SERVICE SECTOR AND BUDGETERY CONTROL 9

Just-in-time approach, Material Requirement Planning, Enterprise Resource Planning, Activity-Based Cost Management, Bench Marking; Balanced Score Card and Value-Chain Analysis, Budgetary Control: Flexible Budgets; Performance budgets; Zero-based budgets.

UNIT V QUANTITATIVE TECHNIQUES FOR COST MANAGEMENT 9

Linear Programming, PERT/CPM, Transportation problems, Assignment problems, Learning Curve Theory.

TOTAL: 45 PERIODS

OUTCOMES

CO1 – Understand the costing concepts and their role in decision making
CO2–Understand the project management concepts and their various aspects in selection
CO3–Interpret costing concepts with project execution
CO4–Gain knowledge of costing techniques in service sector and various budgetary control techniques
CO5 - Become familiar with quantitative techniques in cost management

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓		✓			✓	✓		✓	✓
CO2	✓	✓	✓		✓				✓		✓	✓
CO3	✓	✓	✓		✓	✓					✓	✓
CO4	✓	✓	✓		✓		✓				✓	✓
CO5	✓	✓	✓		✓	✓	✓				✓	✓

REFERENCES:

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OE5095 COMPOSITE MATERIALS L T P C
3 0 0 3

OBJECTIVES:

- Summarize the characteristics of composite materials and effect of reinforcement in composite materials.
- Identify the various reinforcements used in composite materials.
- Compare the manufacturing process of metal matrix composites.
- Understand the manufacturing processes of polymer matrix composites.
- Analyze the strength of composite materials.

UNIT I INTRODUCTION 9

Definition – Classification and characteristics of Composite materials - Advantages and application of composites - Functional requirements of reinforcement and matrix - Effect of reinforcement (size, shape, distribution, volume fraction) on overall composite performance.

UNIT II REINFORCEMENTS 9

Preparation-layup, curing, properties and applications of glass fibers, carbon fibers, Kevlar fibers and Boron fibers - Properties and applications of whiskers, particle reinforcements - Mechanical Behavior of composites: Rule of mixtures, Inverse rule of mixtures - Isostrain and Isostress conditions.

UNIT III MANUFACTURING OF METAL MATRIX COMPOSITES 9

Casting – Solid State diffusion technique - Cladding – Hot isostatic pressing - Properties and applications. Manufacturing of Ceramic Matrix Composites: Liquid Metal Infiltration – Liquid phase sintering. Manufacturing of Carbon – Carbon composites: Knitting, Braiding, Weaving - Properties and applications.

UNIT IV MANUFACTURING OF POLYMER MATRIX COMPOSITES 9

Preparation of Moulding compounds and prepregs – hand layup method – Autoclave method – Filament winding method – Compression moulding – Reaction injection moulding - Properties and applications.

UNIT V STRENGTH 9

Laminar Failure Criteria-strength ratio, maximum stress criteria, maximum strain criteria, interacting failure criteria, hygrothermal failure. Laminate first play failure-insight strength; Laminate strength-ply discount truncated maximum strain criterion; strength design using caplet plots; stress concentrations.

TOTAL: 45 PERIODS

OUTCOMES:

- CO1 - Know the characteristics of composite materials and effect of reinforcement in composite materials.
- CO2 – Know the various reinforcements used in composite materials.
- CO3 – Understand the manufacturing processes of metal matrix composites.
- CO4 – Understand the manufacturing processes of polymer matrix composites.

- CO5 – Analyze the strength of composite materials.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1		✓	✓	✓								
CO2		✓	✓	✓	✓						✓	
CO3			✓	✓	✓		✓					
CO4			✓	✓	✓		✓					
CO5				✓	✓		✓					

REFERENCES:

1. Cahn R.W. - Material Science and Technology – Vol 13 – Composites, VCH, WestGermany.
2. Callister, W.D Jr., Adapted by Balasubramaniam R, Materials Science and Engineering, An introduction, John Wiley & Sons, NY, Indian edition, 2007.
3. Chawla K.K., Composite Materials, 2013.
4. Lubin.G, Hand Book of Composite Materials, 2013.

OE5096 WASTE TO ENERGY L T P C
3 0 0 3

OBJECTIVES:

- Interpret the various types of wastes from which energy can be generated
- Develop knowledge on biomass pyrolysis process and its applications
- Develop knowledge on various types of biomass gasifiers and their operations
- Invent knowledge on biomass combustors and its applications on generating energy
- Summarize the principles of bio-energy systems and their features

UNIT I INTRODUCTION TO EXTRACTION OF ENERGY FROM WASTE 9

Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors

UNIT II BIOMASS PYROLYSIS 9

Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods - Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.

UNIT III BIOMASS GASIFICATION 9

Gasifiers – Fixed bed system – Downdraft and updraft gasifiers – Fluidized bed gasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating – Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.

UNIT IV BIOMASS COMBUSTION 9

Biomass stoves – Improved chullahs, types, some exotic designs, Fixed bed combustors, Types, inclined grate combustors, Fluidized bed combustors, Design, construction and operation - Operation of all the above biomass combustors.

UNIT V BIO ENERGY 9

Properties of biogas (Calorific value and composition), Biogas plant technology and status - Bio energy system - Design and constructional features - Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - Direct combustion - biomass gasification - pyrolysis and liquefaction - biochemical conversion - anaerobic digestion - Types of biogas Plants – Applications - Alcohol production from biomass - Bio diesel production -Urban waste to energy conversion - Biomass energy programme in India.

TOTAL: 45 PERIODS

OUTCOMES:

CO1 – Understand the various types of wastes from which energy can be generated
CO2 – Gain knowledge on biomass pyrolysis process and its applications
CO3 – Develop knowledge on various types of biomass gasifiers and their operations
CO4 – Gain knowledge on biomass combustors and its applications on generating energy
CO5 – Understand the principles of bio-energy systems and their features

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓		✓									✓
CO2	✓		✓									✓
CO3	✓	✓	✓		✓							✓
CO4	✓	✓	✓		✓		✓					✓
CO5	✓	✓	✓		✓							✓

REFERENCES:

1. Biogas Technology - A Practical Hand Book - Khandelwal, K. C. and Mahdi, S. S., Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983.
2. Biomass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996.
3. Food, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991.
4. Non Conventional Energy, Desai, Ashok V., Wiley Eastern Ltd., 1990.

AUDIT COURSES (AC)

AX5091 ENGLISH FOR RESEARCH PAPER WRITING L T P C
2 0 0 0

OBJECTIVES

- Teach how to improve writing skills and level of readability
- Tell about what to write in each section
- Summarize the skills needed when writing a Title
- Infer the skills needed when writing the Conclusion
- Ensure the quality of paper at very first-time submission

UNIT I INTRODUCTION TO RESEARCH PAPER WRITING 6

Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness

UNIT II PRESENTATION SKILLS 6

Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticizing, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts, Introduction

UNIT III TITLE WRITING SKILLS 6

Key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check

UNIT IV RESULT WRITING SKILLS 6

Skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions

UNIT V VERIFICATION SKILLS 6

Useful phrases, checking Plagiarism, how to ensure paper is as good as it could possibly be the first- time submission

TOTAL: 30 PERIODS

OUTCOMES

CO1 –Understand that how to improve your writing skills and level of readability
CO2 – Learn about what to write in each section
CO3 – Understand the skills needed when writing a Title
CO4 – Understand the skills needed when writing the Conclusion
CO5 – Ensure the good quality of paper at very first-time submission

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1										✓		✓
CO2										✓		✓
CO3										✓		✓
CO4										✓		✓
CO5										✓		✓

REFERENCES

1. Adrian Wallwork , English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011
2. Day R How to Write and Publish a Scientific Paper, Cambridge University Press 2006
3. Goldbort R Writing for Science, Yale University Press (available on Google Books) 2006
4. Highman N, Handbook of Writing for the Mathematical Sciences, SIAM. Highman's book 1998.

AX5092 DISASTER MANAGEMENT L T P C
2 0 0 0

OBJECTIVES

- Summarize basics of disaster
- Explain a critical understanding of key concepts in disaster risk reduction and humanitarian response.
- Illustrate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.

- Describe an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.
- Develop the strengths and weaknesses of disaster management approaches

UNIT I INTRODUCTION 6

Disaster: Definition, Factors and Significance; Difference between Hazard And Disaster; Natural and Manmade Disasters: Difference, Nature, Types and Magnitude.

UNIT II REPERCUSSIONS OF DISASTERS AND HAZARDS 6

Economic Damage, Loss of Human and Animal Life, Destruction Of Ecosystem. Natural Disasters: Earthquakes, Volcanisms, Cyclones, Tsunamis, Floods, Droughts And Famines, Landslides And Avalanches, Man-made disaster: Nuclear Reactor Meltdown, Industrial Accidents, Oil Slicks And Spills, Outbreaks Of Disease And Epidemics, War And Conflicts.

UNIT III DISASTER PRONE AREAS IN INDIA 6

Study of Seismic Zones; Areas Prone To Floods and Droughts, Landslides And Avalanches; Areas Prone To Cyclonic and Coastal Hazards with Special Reference To Tsunami; Post-Disaster Diseases and Epidemics

UNIT IV DISASTER PREPAREDNESS AND MANAGEMENT 6

Preparedness: Monitoring Of Phenomena Triggering a Disaster or Hazard; Evaluation of Risk: Application of Remote Sensing, Data from Meteorological And Other Agencies, Media Reports: Governmental and Community Preparedness.

UNIT V RISK ASSESSMENT 6

Disaster Risk: Concept and Elements, Disaster Risk Reduction, Global and National Disaster Risk Situation. Techniques of Risk Assessment, Global Co-Operation in Risk Assessment and Warning, People's Participation in Risk Assessment. Strategies for Survival

TOTAL : 30 PERIODS

OUTCOMES

CO1: Ability to summarize basics of disaster

CO2: Ability to explain a critical understanding of key concepts in disaster risk reduction and humanitarian response.

CO3: Ability to illustrate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.

CO4: Ability to describe an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.

CO5: Ability to develop the strengths and weaknesses of disaster management approaches

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓											
CO3	✓	✓	✓									
CO4	✓	✓	✓									
CO5	✓	✓	✓									

REFERENCES

1. Goel S. L., Disaster Administration And Management Text And Case Studies", Deep & Deep Publication Pvt. Ltd., New Delhi,2009.
2. NishithaRai, Singh AK, "Disaster Management in India: Perspectives, issues and strategies "'NewRoyal book Company,2007.

3. Sahni, PardeepEt.Al. ," Disaster Mitigation Experiences And Reflections", Prentice Hall OfIndia, New Delhi,2001.

AX5093 SANSKRIT FOR TECNICAL KNOWLEDGE L T P C
2 0 0 0

OBJECTIVES

- Illustrate the basic sanskrit language.
- Recognize sanskrit, the scientific language in the world.
- Appraise learning of sanskrit to improve brain functioning.
- Relate sanskrit to develop the logic in mathematics, science & other subjects enhancing the memory power.
- Extract huge knowledge from ancient literature.

UNIT I ALPHABETS 6

Alphabets in Sanskrit

UNIT II TENSES AND SENTENCES 6

Past/Present/Future Tense - Simple Sentences

UNIT III ORDER AND ROOTS 6

Order - Introduction of roots

UNIT IV SANSKRIT LITERATURE 6

Technical information about Sanskrit Literature

UNIT V TECHNICAL CONCEPTS OF ENGINEERING 6

Technical concepts of Engineering-Electrical, Mechanical, Architecture, Mathematics

TOTAL: 30 PERIODS

OUTCOMES

- CO1 - Understanding basic Sanskrit language.
- CO2 - Write sentences.
- CO3 - Know the order and roots of Sanskrit.
- CO4 - Know about technical information about Sanskrit literature.
- CO5 - Understand the technical concepts of Engineering.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1										✓		✓
CO2										✓		✓
CO3												✓
CO4												✓
CO5												✓

REFERENCES

1. "Abhyaspustakam" – Dr. Vishwas, Samskrita-Bharti Publication, New Delhi
2. "Teach Yourself Sanskrit" Prathama Deeksha-Vempati Kutumbshastri, Rashtriya Sanskrit Sansthanam, New Delhi Publication
3. "India's Glorious Scientific Tradition" Suresh Soni, Ocean books (P) Ltd., New Delhi, 2017.

AX5094 **VALUE EDUCATION** **L T P C**
2 0 0 0

OBJECTIVES

Students will be able to

- Understand value of education and self-development
- Imbibe good values in students
- Let the should know about the importance of character

UNIT I

Values and self-development–Social values and individual attitudes. Work ethics, Indian vision of humanism. Moral and non-moral valuation. Standards and principles. Value judgements

UNIT II

Importance of cultivation of values. Sense of duty. Devotion, Self-reliance. Confidence, Concentration. Truthfulness, Cleanliness. Honesty, Humanity. Power of faith, National Unity. Patriotism. Love for nature, Discipline

UNIT III

Personality and Behavior Development-Soul and Scientific attitude. Positive Thinking. Integrity and discipline. Punctuality, Love and Kindness. Avoid fault Thinking. Free from anger, Dignity of labour.

Universal brother hood and religious tolerance. True friendship. Happiness Vs suffering, love for truth. Aware of self-destructive habits. Association and Cooperation. Doing best for saving nature

UNIT IV

Character and Competence–Holy books vs Blind faith. Self-management and Good health. Science of reincarnation. Equality, Nonviolence, Humility, Role of Women. All religions and same message. Mind your Mind, Self-control. Honesty, Studying effectively.

TOTAL: 30 PERIODS

OUTCOMES

Students will be able to

- Knowledge of self-development.
- Learn the importance of Human values.
- Developing the overall personality.

Suggested reading

1. Chakroborty, S.K."Values and Ethics for organizations Theory and practice", Oxford University Press, New Delhi.

AX5095 **CONSTITUTION OF INDIA** **L T P C**
2 0 0 0

OBJECTIVES

Students will be able to:

- Understand the premises informing the twin themes of liberty and freedom from a civil rights perspective.
- To address the growth of Indian opinion regarding modern Indian intellectuals' constitutional
- Role and entitlement to civil and economic rights as well as the emergence nation hood in the early years of Indian nationalism.
- To address the role of socialism in India after the commencement of the Bolshevik Revolutionin1917and its impact on the initial drafting of the Indian Constitution.

UNIT I HISTORY OF MAKING OF THE INDIAN CONSTITUTION:

History, Drafting Committee, (Composition & Working)

UNIT II PHILOSOPHY OF THE INDIAN CONSTITUTION:

Preamble, Salient Features

UNIT III CONTOURS OF CONSTITUTIONAL RIGHTS AND DUTIES:

Fundamental Rights, Right to Equality, Right to Freedom, Right against Exploitation, Right to Freedom of Religion, Cultural and Educational Rights, Right to Constitutional Remedies, Directive Principles of State Policy, Fundamental Duties.

UNIT IV ORGANS OF GOVERNANCE:

Parliament, Composition, Qualifications and Disqualifications, Powers and Functions, Executive, President, Governor, Council of Ministers, Judiciary, Appointment and Transfer of Judges, Qualifications, Powers and Functions.

UNIT V LOCAL ADMINISTRATION:

District's Administration head: Role and Importance, • Municipalities: Introduction, Mayor and role of Elected Representative, CEO, Municipal Corporation. Pachayati raj: Introduction, PRI: Zila Pachayat. Elected officials and their roles, CEO Zila Pachayat: Position and role. Block level: Organizational Hierarchy(Different departments), Village level:Role of Elected and Appointed officials, Importance of grass root democracy.

UNIT VI ELECTION COMMISSION:

Election Commission: Role and Functioning. Chief Election Commissioner and Election Commissioners - Institute and Bodies for the welfare of SC/ST/OBC and women.

TOTAL: 30 PERIODS

OUTCOMES

Students will be able to:

- Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.
- Discuss the intellectual origins of the framework of argument that informed the conceptualization
- of social reforms leading to revolution in India.
- Discuss the circumstances surrounding the foundation of the Congress Socialist Party[CSP] under the leadership of Jawaharlal Nehru and the eventual failure of the proposal of direct elections through adult suffrage in the Indian Constitution.
- Discuss the passage of the Hindu Code Bill of 1956.

Suggested reading

1. The Constitution of India,1950(Bare Act),Government Publication.
2. Dr.S.N.Busi, Dr.B. R.Ambedkar framing of Indian Constitution,1st Edition, 2015.
3. M.P. Jain, Indian Constitution Law, 7th Edn., Lexis Nexis,2014.

research project (MUSTER) country report 1.London:DFID.
4. Akyeampong K, Lussier K, Pryor J, Westbrook J (2013) Improving teaching and learning of basic maths and reading in Africa: Does teacher preparation count? International Journal Educational Development, 33(3): 272–282.
5. Alexander RJ(2001) Culture and pedagogy: International comparisons in primary education. Oxford and Boston: Blackwell.
6. Chavan M(2003) Read India: Amass scale, rapid, 'learning to read' campaign.
7. www.pratham.org/images/resource%20working%20paper%202.pdf.

AX5097 **STRESS MANAGEMENT BY YOGA** **L T P C**
2 0 0 0

OBJECTIVES
- To achieve overall health of body and mind
- To overcome stress

UNIT I
Definitions of Eight parts of yoga.(Ashtanga)

UNIT II
Yam and Niyam - Do's and Don't's in life - i) Ahinsa, satya, astheya, bramhacharya and aparigraha, ii) Ahinsa, satya, astheya, bramhacharya and aparigraha.

UNIT III
Asan and Pranayam - Various yog poses and their benefits for mind & body - Regularization of breathing techniques and its effects-Types of pranayam

TOTAL: 30 PERIODS

OUTCOMES
Students will be able to:
- Develop healthy mind in a healthy body thus improving social health also
- Improve efficiency

SUGGESTED READING
1. 'Yogic Asanas for Group Tarining-Part-I":Janardan Swami Yoga bhyasi Mandal, Nagpur
2. "Rajayoga or conquering the Internal Nature" by Swami Vivekananda, Advaita Ashrama (Publication Department), Kolkata

AX5098 **PERSONALITY DEVELOPMENT THROUGH LIFE ENLIGHTENMENT SKILLS** **L T P C**
2 0 0 0

OBJECTIVES
- To learn to achieve the highest goal happily
- To become a person with stable mind, pleasing personality and determination
- To awaken wisdom in students

UNIT I
Neetisatakam-holistic development of personality - Verses- 19,20,21,22 (wisdom) - Verses-29,31,32 (pride & heroism) – Verses- 26,28,63,65 (virtue) - Verses- 52,53,59 (dont's) - Verses-71,73,75,78 (do's)

UNIT II

Approach to day to day work and duties - Shrimad Bhagwad Geeta: Chapter 2-Verses 41, 47,48 - Chapter 3-Verses 13, 21, 27, 35 Chapter 6-Verses 5,13,17,23, 35 - Chapter 18-Verses 45, 46, 48.

UNIT III

Statements of basic knowledge - Shrimad Bhagwad Geeta: Chapter2-Verses 56, 62, 68 Chapter 12 -Verses 13, 14, 15, 16,17, 18 - Personality of role model - shrimad bhagwad geeta - Chapter2-Verses 17, Chapter 3-Verses 36,37,42 - Chapter 4-Verses 18, 38,39 Chapter18 – Verses 37,38,63

TOTAL: 30 PERIODS

OUTCOMES

Students will be able to

- Study of Shrimad-Bhagwad-Geeta will help the student in developing his personality and achieve the highest goal in life
- The person who has studied Geeta will lead the nation and man kind to peace and prosperity
- Study of Neet is hatakam will help in developing versatile personality of students.

Suggested reading

1. Gopinath, Rashtriya Sanskrit Sansthanam P, Bhartrihari's Three Satakam, Niti-sringar-vairagya, New Delhi,2010
2. Swami Swarupananda , Srimad Bhagavad Gita, Advaita Ashram, Publication Department, Kolkata, 2016.