SRM VALLIAMMAI ENGINEERING COLLEGE

(AN AUTONOMOUS INSTITUTION)

SRM Nagar, Kattankulathur - 603 203.

(Approved by AICTE, Affiliated to Anna University, 'A' Grade Accredited by NAAC, NBA Accredited, ISO 9001: 2015 Certified)

CURRICULA AND SYLLABI

M.E.– POWER SYSTEMS ENGINEERING

REGULATION 2023

Vision of the Department

To accomplish and maintain international eminence and to contribute to become a model institution for higher learning through development of highly competent and dynamic Electrical and Electronics Engineers while remaining sensitive to ethical, societal and environmental issues.

Mission of the Department

- ✓ To mould Electrical and Electronics Engineers and Entrepreneurs of international excellence as global leaders capable of contributing towards technological innovations, economic growth and environmental safety.
- ✓ To transform the Department into centre of excellence in the domain of Electrical and Electronics engineering by promoting research and development, consultancy work and industry- institute interaction activities.

SRM VALLIAMMAI ENGINEERING COLLEGE

(An Autonomous Institution, Affiliated to Anna University, Chennai)

M.E. POWER SYSTEMS ENGINEERING

REGULATIONS – 2023

1. PROGRAMME EDUCATIONAL OBJECTIVES(PEOs)

I	Get elevated as technically competent Power Engineer to cater the needs of Electrical Power Industry, Research and Educational Institutions.
II	Become an entrepreneur in modern restructured power systems, proficient in application software packages used in Power System industry.
III	Pursue career in core service sector of power system industry with life long learning and professional ethics.

2.PROGRAMME OUTCOMES(POs)

PO#	Programme Outcomes
1	An ability to independently carry out research/ investigation and development work to solve practical problems.
2	An ability to write and present a substantial technical report/document.
3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
4	Ability to attain professional ethics and intellectual integrity to contribute to the community for sustainable development of society.
5	Apply knowledge of basic science and engineering in analysis and modeling of the power system components.
6	Implement cost effective and cutting edge technologies in Power System

3. MAPPING OF PEOs with POs

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

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

			PO1	PO2	PO3	PO4	PO5	PO6
Year I	Sem I	MA3123-Advanced Mathematics for Electrical and Instrumentation Engineering	3.0	2.0	2.0	1.0	2.0	1.0
		PS3161-Advanced Power System Analysis	1.8	2.0	2.7	-	2.3	2.0
		PS3162-Power System Operation and Control	1.33	2.0	-	1.67	2.2	2.75
		PS3163-Analysis and Computation of Electromagnetic Transients in Power Systems	2.6	1.25	2.8	2.4	3.0	3.0
		PS3164-System Theory	2.8	2.0	2.8	2.0	2.5	2.5
		PS3165-Restructured Power System	3.0	1.0	2.0	3.0	-	-
		PS3166-Power System Simulation Laboratory-I	1.0	2.0	1.33	1.8	2.0	1.25
		PS3167-Power System Simulation Laboratory-II	3.0	2.0	3.0	2.0	2.4	2.6
Year I	Sem II	PS3261-Power System Dynamics	3.0	1.0	3.0	2.4	2.0	3.0
		PS3262-HVDC and FACTS	2.6	1.2	3.0	2.4	2.0	3.0
		PS3263-Advanced Power System Protection	1.8	2.4	2.4	2.6	2.2	1.4
		Professional Elective - I PPS101-Power System State Estimation and Security Assessment	1.0	1.3	1.0	1.0	1.0	1.5
		Professional Elective- I PPS102-Optimization Techniques to Power System Engineering	2.0	-	-	1.0	-	-
		Professional Elective-I PPS103-Computational Intelligence Techniques to Power Systems	2.0	2.25	2.0	1.5	2.66	1.5
		Professional Elective-I PPS104- IoT for Smart Systems	1.75	2.0	2.3	2.3	3.0	3.0
		Professional Elective-I PPS105-Renewable Energy and Grid Integration	1.6	2.0	1.4	1.5	1.25	2.0

		Professional Elective-II PPS201-Electrical Power Distribution System	2.0	1.8	2.0	1.0	2.4	1.8
		Professional Elective-II PPS202-Wind and Solar Energy Systems	2.4	1.6	2.5	1.5	2.4	2.25
		Professional Elective-II PPS203-Distributed Generation and Micro Grid	1.75	2.0	2.3	1.2	2.6	1.2
		Professional Elective-II PPS204-Energy Storage Technologies	2.25	1.6	2.25	1	2.6	3.0
		Professional Elective-II PPS205-Power Quality	3.0	-	3.0	3.0	3.0	2.0
		Professional Elective-III PPS301-Power System Reliability	2.4	1.6	2.4	0.4	2.6	2.2
		Professional Elective-III PPS302- EHV AC Transmission	3.0	3.0	3.0	3.0	3.0	3.0
		Professional Elective-III PCU101-Electromagnetic Interference and Compatibility in SystemDesign	3.0	2.6	2.2	2.2	1.6	1.2
		Professional Elective-III PPS303- Industrial Power SystemAnalysis and Design	1.0	2.0	2.0	1.0	1.66	1.5
		Professional Elective-III PPS304- Advanced Power System Dynamics	2.0	2.0	2.4	-	-	-
		PS3264-Advanced Power System Simulation Laboratory	2.0	1.4	3.0	2.0	2.0	3.0
		PS3241-Mini Project	3.0	2.0	2.0	2.0	2.0	2.0
		BA3371-Research Methodology and IPR						
		Professional Elective-IV & V PPS401-Computer Relaying and Wide Area Measurement Systems	2.0	1.0	1.0	1.0	2.0	-

Year II	Sem III	**Professional Elective-IV & V** PPS402-Application of DSP To Power System Protection	1.4	1.75	1.8	1.5	2.33	1.0
		Professional Elective-IV & V PPS403-Power System Instrumentation	2.4	1.8	1.2	2.0	1.8	2.0
		Professional Elective-IV & V PPS501-High Voltage Technology	3.0	1.0	2.0	2.0	1.0	1.0
		Professional Elective-IV & V PPS502-Electric Vehicles and Power Management	3.0	1.0	2.0	1.0	-	3.0
		Professional Elective-IV & V PPS503-Energy Management and Auditing	2.0	2.4	2.0	1.0	2.0	2.0
		Professional Elective-IV & V PPS504-Smart Grid	1.0	2.0	2.0	1.0	1.33	1.67
		Professional Elective-IV & V PPS505- Renewable Energy Systems	2.8	1.6	3.0	1.5	2.4	2.25
		PS3341-Technical Seminar	3.0	2.0	-	-	-	-
		PS3342-Internship (4 Weeks)	2.0	1.0	1.0	1.0	2.0	2.0
		PS3343-Project Work Phase-I	3.0	2.0	3.0	2.4	1.8	1.8
Year II	Sem IV	PS3441-Project Work Phase-II	3.0	3.0	1.6	1.8	1.0	1.0

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REGULATIONS-2023

CHOICE BASED CREDIT SYSTEM

M.E. POWER SYSTEMS ENGINEERING

CURRICULUM FOR SEMESTERS I TO IV

Semester - I

S.No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
THEORY								
1	MA3123	Advanced Mathematics for Electrical and Instrumentation Engineering	BSC	4	4	0	0	4
2	PS3161	Advanced Power System Analysis	PCC	3	3	0	0	3
3	PS3162	Power System Operation and Control	PCC	3	3	0	0	3
4	PS3163	Analysis and Computation of Electromagnetic Transients in Power Systems	PCC	3	3	0	0	3
5	PS3164	System Theory	PCC	3	3	0	0	3
6	PS3165	Restructured Power System	PCC	3	3	0	0	3
PRACTICAL								
7	PS3166	Power System Simulation Laboratory - I	PCC	4	0	0	4	2
8	PS3167	Power System Simulation Laboratory - II	PCC	4	0	0	4	2
			TOTAL	**27**	**19**	**0**	**8**	**23**

Semester - II

S.No.	Course Code	Course Title	Category	Contact Periods	L	T	P	C
THEORY								
1	PS3261	Power System Dynamics	PCC	3	3	0	0	3
2	PS3262	HVDC and FACTS	PCC	3	3	0	0	3
3	PS3263	Advanced Power System Protection	PCC	3	3	0	0	3
4	PPS1XX	Professional Elective - I	PEC	3	3	0	0	3
5	PPS2XX	Professional Elective - II	PEC	3	3	0	0	3
6	PPS3XX	Professional Elective - III	PEC	3	3	0	0	3
PRACTICAL								
7	PS3264	Advanced Power System Simulation Laboratory	PCC	4	0	0	4	2
8	PS3241	Mini Project	EEC	4	0	0	4	2
			TOTAL	**26**	**18**	**0**	**8**	**22**

Semester - III								
S.No.	**Course Code**	**Course Title**	**Category**	**Contact Periods**	**L**	**T**	**P**	**C**
THEORY								
1	**BA3371**	Research Methodology and IPR	RMC	3	3	0	0	3
2	**PPS4XX**	Professional Elective - IV	PEC	3	3	0	0	3
3	**PPS5XX**	Professional Elective - V	PEC	3	3	0	0	3
PRACTICAL								
4	**PS3341**	Technical Seminar	EEC	2	0	0	2	1
5	**PS3342**	Internship (4 Weeks)	EEC	0	0	0	0	2
6	**PS3343**	Project Work Phase - I	EEC	12	0	0	12	6
			TOTAL	**23**	**9**	**0**	**14**	**18**

Semester - IV								
S.No.	**Course Code**	**Course Title**	**Category**	**Contact Periods**	**L**	**T**	**P**	**C**
PRACTICAL								
1	**PS3441**	Project Work Phase - II	EEC	24	0	0	24	12
			TOTAL	**24**	**0**	**0**	**24**	**12**

Total Credits: 75

PROFESSIONAL ELECTIVE COURSES

PROFESSIONAL ELECTIVE - I								
S.No	**Course Code**	**Course Title**	**Category**	**Contact Periods**	**L**	**T**	**P**	**C**
THEORY								
1	**PPS101**	Power System State Estimation and Security Assessment	PEC	3	3	0	0	3
2	**PPS102**	Optimization Techniques to Power System Engineering	PEC	3	3	0	0	3
3	**PPS103**	Computational Intelligence Techniques to Power Systems	PEC	3	3	0	0	3
4	**PPS104**	IoT for Smart Systems	PEC	3	3	0	0	3
5	**PPS105**	Renewable Energy and Grid Integration	PEC	3	3	0	0	3

PROFESSIONAL ELECTIVES - II								
S.No.	**Course Code**	**Course Title**	**Category**	**Contact Periods**	**L**	**T**	**P**	**C**
THEORY								
1	**PPS201**	Electrical Power Distribution System	PEC	3	3	0	0	3
2	**PPS202**	Wind and Solar Energy Systems	PEC	3	3	0	0	3
3	**PPS203**	Distributed Generation and Micro Grid	PEC	3	3	0	0	3
4	**PPS204**	Energy Storage Technologies	PEC	3	3	0	0	3
5	**PPS205**	Power Quality	PEC	3	3	0	0	3

PROFESSIONAL ELECTIVE - III								
S.No.	**Course Code**	**Course Title**	**Category**	**Contact Periods**	**L**	**T**	**P**	**C**
THEORY								
1	**PPS301**	Power System Reliability	PEC	3	3	0	0	3
2	**PPS302**	EHV AC Transmission	PEC	3	3	0	0	3
3	**PCU101**	Electromagnetic Interference and Compatibility in System Design	PEC	3	3	0	0	3

4	**PPS303**	Industrial Power System Analysis and Design	PEC	3	3	0	0	3
5	**PPS304**	Advanced Power System Dynamics	PEC	3	3	0	0	3

PROFESSIONAL ELECTIVES - IV & V								
S.No.	**Course Code**	**Course Title**	**Category**	**Contact Periods**	**L**	**T**	**P**	**C**
THEORY								
1	**PPS401**	Computer Relaying and Wide Area Measurement Systems	PEC	3	3	0	0	3
2	**PPS402**	Application of DSP To Power System Protection	PEC	3	3	0	0	3
3	**PPS403**	Power System Instrumentation	PEC	3	3	0	0	3
4	**PPS501**	High Voltage Technology	PEC	3	3	0	0	3
5	**PPS502**	Electric Vehicles and Power Management	PEC	3	3	0	0	3
6	**PPS503**	Energy Management and Auditing	PEC	3	3	0	0	3
7	**PPS504**	Smart Grid	PEC	3	3	0	0	3
8	**PPS505**	Renewable Energy Systems	PEC	3	3	0	0	3

SUMMARY

Sl.No	**Subject Area**	**Credits per Semester**				**Total Credits**
		I	**II**	**III**	**IV**	
1	FC	4				4
2	PCC	19	11			30
3	PEC		9	6		15
4	RMC			3		3
5	EEC		2	9	12	23
6	**Total**	**23**	**22**	**18**	**12**	**75**

SEMESTER – I

MA3123 ADVANCED MATHEMATICS FOR ELECTRICAL AND INSTRUMENTATION ENGINEERING

L	T	P	C
4	0	0	4

COURSE OBJECTIVES:

1. This course also will help study the decomposition of matrices and Matrix Theory.
2. The students to identify, formulate, abstract, and solve problems in Calculus of Variations.
3. This course covers the concept of Random Variables and standard Distributions.
4. The extensive experience with the tactics of linear programming problem solving and logical thinking applicable in Electrical engineering.
5. The primary objective of this course is to demonstrate various analytical skills in applied mathematics

UNIT - I MATRIX THEORY 12

Cholesky decomposition Generalized Eigenvectors - QR Factorization-Least squares method-Singular value decomposition.

UNIT - II CALCULUS OF VARIATIONS 12

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

UNIT - III RANDOM VARIABLES AND DISTRIBUTIONS 12

Random variables-Probability function–Moments–Moment generating functions Binomial, Poisson, Geometric, Uniform, Exponential, and Normal distributions.

UNIT - IV LINEAR PROGRAMMING 12

Formulation–Graphical solution–Simplex method -Transportation and Assignment models.

UNIT - V FOURIER SERIES 12

Fourier trigonometric series: Periodic function as power signals–Convergence of series–Even and odd function – Half range Cosine and sine series –Exponential Fourier series–Parseval's theorem and Harmonic Analysis.

TOTAL: 60 PERIODS

COURSE OUTCOMES

1. Apply various methods in matrix theory to solve system of linear equations.
2. Maximizing and minimizing the functional that occur in electrical engineering discipline.
3. Understand the concept of Random variables and standard distributions.
4. Could develop a fundamental understanding of linear programming models, able to apply the Simplex method for solving linear programming problems.
5. Solving Fourier series analysis both periodic and Non Periodic functions and its uses in representing the power signal.

REFERENCES

1. Andrews L.C. and Phillips R.L., "Mathematical Techniques for Engineers and Scientists", Prentice Hall of India Pvt. Ltd., New Delhi, 2005.
2. Bronson, R. "Matrix Operation", Schaum's outline series,2nd Edition, McGraw Hill, 2011.
3. Elsgolc, L. D. "Calculus of Variations", Dover Publications, New York, 2007.
4. Johnson, R.A., Miller, I and Freund J., "Miller and Freund's Probability and Statistics for Engineers", Pearson Education, Asia, 8th Edition, 2015.
5. O'Neil, P.V., "Advanced Engineering Mathematics", Thomson Asia Pvt. Ltd., Singapore, 2003.
6. Taha, H.A., "Operations Research, An Introduction", 9th Edition, Pearson Education, New Delhi, 2016.

CO - PO MAPPING

MA3123	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	2	2	1	2	1
CO2	3	2	2	1	2	1
CO3	3	2	2	1	2	1
CO4	3	2	2	1	2	1
CO5	3	2	2	1	2	1
Average	**3.0**	**2.0**	**2.0**	**1.0**	**2.0**	**1.0**

PS3161	ADVANCED POWER SYSTEM ANALYSIS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To introduce various solution techniques to solve the large-scale power systems.
2. To impart in-depth knowledge on different power flow solution methods for large power system networks.
3. To perform various optimal power flow methods involving operating and security constraints.
4. To perform short circuit fault analysis for various fault conditions on three phase basis.
5. To Illustrate different numerical integration methods and factors influencing transient stability.

UNIT - I SOLUTION TECHNIQUE 9

Sparse Matrix techniques for large scale power systems - Optimal ordering schemes for preserving sparsity - Flexible packed storage scheme for storing matrix as compact arrays - Factorization by Bi-factorization and Gauss elimination methods - Repeat solution using Left and Right factors and L and U matrices.

UNIT - II POWER FLOW ANALYSIS 9

Power flow equation in real and polar forms - Review of Newton Raphson method for solution; Adjustment of P-V buses - Review of Fast Decoupled Power Flow method - Sensitivity factors for P-V bus adjustment.

UNIT - III OPTIMAL POWER FLOW 9

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 - IV SHORT CIRCUIT ANALYSIS 9

Formation of bus impedance matrix with mutual coupling (single phase basis and three phase basis) - Computer method for fault analysis using ZBUS and sequence components - Derivation of equations for bus voltages -fault current and line currents - both in sequence and phase - symmetrical and unsymmetrical faults.

UNIT - V TRANSIENT STABILITY ANALYSIS 9

Introduction - Numerical Integration Methods - Euler and Fourth Order Runge-Kutta methods - Algorithm for simulation of SMIB and multi-machine system with classical synchronous machine model - Factors influencing transient stability - Numerical stability and implicit Integration methods. Methods to improve the transient stability limit.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Ability to solve large scale simultaneous linear equations and the ordering schemes for preserving sparsity.
2. Ability to solve large scale power flow problems.
3. Ability to solve optimal power flow problem using various solution methods.
4. Ability to do fault calculations for various fault conditions on three phase basis.
5. Ability to do stability studies under various disturbances using numerical integration methods.

REFERENCES

1. A. J. Wood and B. F. Wollenberg, "Power Generation Operation and Control", John Wiley and sons, New York, 2016.
2. M. A. Pai," Computer Techniques in Power System Analysis",Tata McGraw Hill Publishing Company Limited, New Delhi, 2006.
3. D. P. Kothari and I. J. Nagrath, 'Modern Power System Analysis', Fourth Edition, Tata McGraw Hill Publishing Company Limited, New Delhi, 2011.
4. G W Stagg, A.H El. Abiad, "Computer Methods in Power System Analysis", McGraw Hill,1968.

5. P. Kundur, “Power System Stability and Control”, McGraw Hill, 1994.
6. K. Zollenkopf, “Bi-Factorization: Basic Computational Algorithm and Programming Techniques ; pp:75-96 ; Book on “Large Sparse Set of Linear Systems” Editor:J.K.Rerd, Academic Press, 1971.

CO - PO MAPPING

PS3161	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	2	-	-	-	3	1
CO2	3	3	3	-	3	3
CO3	2	2	3	-	-	2
CO4	1	1	2	-	-	-
CO5	1	2	-	-	1	-
Average	**1.8**	**2.0**	**2.7**	-	**2.3**	**2.0**

PS3162 POWER SYSTEM OPERATION AND CONTROL

	L	T	P	C
	3	0	0	3

COURSE OBJECTIVES

1. To understand the fundamentals of speed governing system and the concept of control areas.
2. To get the insight of load frequency control and its modelling.
3. To provide knowledge about Hydrothermal scheduling, Unit commitment and solution techniques.
4. To realize the requirements and methods of real and reactive power control in power system.
5. To be familiar with the power system security issues and contingency studies.

UNIT - I INTRODUCTION 9

System load variation: System load characteristics, load curves - daily, weekly and annual, load duration curve, load factor, diversity factor. Reserve requirements: Installed reserves, spinning reserves, cold reserves, hot reserves. Overview of system operation and Control: Load forecasting, techniques of forecasting, Indian power sector – Past and present status: Recent growth of power sector in India – An overview, A time line of the Indian power sector, Players in the Indian power sector, basics of power system operation and control.

UNIT - II LOAD FREQUENCY CONTROL 9

Need for frequency and voltage control - Plant and system level control - modeling of LFC of single area system - static and dynamic analysis - LFC of two area system - static and dynamic analysis - Tie line bias control - development of state variable model of single and two area system, Economic Dispatch Control.

UNIT - III HYDROTHERMAL SCHEDULING PROBLEM 9

Hydrothermal coordination – hydroelectric plant models - short term and long-term scheduling problem – gradient approach – Hydro units in series - Hydro-thermal scheduling with pumped hydro plant: Scheduling of systems using Dynamic programming and linear programming Selection of initial feasible trajectory for pumped hydro plant.

UNIT - IV UNIT COMMITMENT AND ECONOMIC DISPATCH 9

Statement of Unit Commitment (UC) problem; constraints in UC: spinning reserve, thermal unit constraints, hydro constraints, fuel constraints and other constraints; UC solution methods: Priority-list methods, forward dynamic programming approach, numerical problems. Incremental cost curve, coordination equations without loss and with loss, solution by direct method and λ-iteration method. Gradient method- Newton's method – Base point and participation factor method. Economic dispatch controller added to LFC control.

UNIT - V POWER SYSTEM SECURITY 9

Need for power system Security- - Contingency analysis – linear sensitivity factors – AC power flow methods – contingency selection – concentric relaxation – bounding-security constrained optimal power flow-Interior point algorithm-Bus incremental costs.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Explain about the operation and control of power system and List the past and present status of Indian power sector.
2. Develop the static and dynamic model of Load Frequency Control in single and two area system.
3. Analyse the problems associated with hydro thermal Scheduling and to construct the algorithm for feasible load management.
4. Distinguish between various methods involved in unit commitment and economic dispatch problems.
5. Define about the power system security factors and analyse the algorithms used for optimal power.

REFERENCES

1. I.J.Nagrath & D.P.Kothari, Modern Power System Analysis, 5th Edition, McGraw Hill higher Education, New Delhi, 2022.
2. Abhijit Chakrabarti and Sunita Halder, Power System Analysis, Operation and Control, PHI, Third edition, 2012.
3. P.S.R.Murthy, Power System operation and Control, 1st Edition, Tata McGraw Hill Publishers, 2008.
4. Allen.J.Wood and Bruce F.Wollenberg, “Power Generation, Operation and Control”, John Wiley & Sons, Inc., 2003.
5. Olle. I. Elgerd, “Electric Energy Systems Theory – An Introduction”, Tata McGraw Hill Publishing Company Ltd, New Delhi, Second Edition, 2003.
6. L.L. Grigsby, “The Electric Power Engineering, Hand Book”, CRC Press & IEEE Press, 2001.
7. P. Kundur, “Power System Stability & Control”, McGraw Hill Publications, USA, 1994.
8. John D.grainger, William D,”Power System Analysis”, International edition, McGraw Hill Publications, USA, 1994.

CO - PO and CO - PSO MAPPING

PS3162	PROGRAM OUTCOMES					
	1	2	3	4	5	6
CO1	-	3	-	2	2	-
CO2	-	-	-	-	3	2
CO3	1	2	-	1	2	3
CO4	2	1	-	2	2	3
CO5	1	2	-	-	2	3
Average	1.33	2.0	-	1.67	2.2	2.75

PS3163	ANALYSIS AND COMPUTATION OF ELECTROMAGNETIC TRANSIENTS IN POWER SYSTEMS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To understand the various parameters of travelling waves and Insulation coordination.
2. To understand the Lightning, Switching and temporary over voltages.
3. To understand the Over Head transmission line parameters.
4. To understand the modeling and function of cables.
5. To understand the concept of EMTP in power system.

UNIT - I REVIEW OF TRAVELLING WAVE PHENOMENA AND INSULATION COORDINATION 9

Lumped and Distributed Parameters – Wave Equation – Reflection, Refraction, Behaviour of Travelling waves at the line terminations – Lattice Diagrams – Attenuation and Distortion. Insulation co-ordination –volt –time characteristics, Insulation strength and their selection-Evaluation of insulation strength standard BILs-Characteristics of protective devices, applications.

UNIT - II LIGHTNING, SWITCHING AND TEMPORARY OVER VOLTAGES 9

Lightning over voltages: interaction between lightning and power system- ground wire voltage and voltage across insulator; switching overvoltage: short line or kilometric fault, energizing transients- closing and re-closing of lines, methods of control; temporary over voltages: line dropping, load rejection; voltage induced by fault; Very Fast Transient Overvoltage (VFTO).

UNIT - III PARAMETERS AND MODELING OF OVERHEAD LINES 9

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

UNIT - IV PARAMETERS AND MODELING OF UNDERGROUND CABLES 9

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 - V COMPUTATION OF POWER SYSTEM TRANSIENTS 9

Digital computation of line parameters: Necessity of 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 using EUROSTAG and PSCAD.

TOTAL: 45 PERIODS

COURSE OUTCOMES

At the end of this course, learners will be able to:

1. Understand the concept of travelling waves and Insulation Coordination.
2. Understand various types of over voltages.

3. Understand the modeling of overhead lines.
4. Understand the modeling of underground cables.
5. Understand the computation of power system transients and EMTP program.

REFERENCE BOOKS:

1. Allan Greenwood "Electrical Transients in Power System", Wiley and sons, Inc., New york, Second Edition, 1991.
2. R. Ramanujam, "Computational Electromagnetic Transients: Modeling, Solution Methods and simulation, I.K. International Publishing House Pvt limited, New delhi 2014.
3. Naidu M S and Kamaraju V, "High Voltage Engineering", Tata McGraw-Hill Publishing company Ltd, New Delhi, Third Edition, 2005
4. Pritindra Chowdhari, "Electromagnetic transients in Power System", John Wiley and Sons Inc., Second Edition, 2009

CO - PO MAPPING

PS3163	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	2	-	3	2	-	3
CO2	2	1	3	2	-	3
CO3	3	1	3	3	3	3
CO4	3	2	2	3	3	3
CO5	3	1	3	2	3	3
Average	**2.6**	**1.25**	**2.8**	**2.4**	**3.0**	**3.0**

PS3164 **SYSTEM THEORY** **L T P C**

3 0 0 3

COURSE OBJECTIVES

1. To understand the modeling and representing systems in state variable form.
2. To provide train on solving linear and non-linear state equations.
3. To understand illustrate the properties of control system.
4. To understand classify non–linearities and examine stability of systems in the sense of Lyapunov's theory.
5. To provide educate on modal concepts, design of state, output feedback controllers and estimators.

UNIT - I STATE VARIABLE REPRESENTATION 9

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

UNIT - II SOLUTION OF STATE EQUATIONS 9

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

UNIT - III PROPERTIES OF THE CONTROL SYSTEM 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 NON-LINEARITIES AND STABILITY ANALYSIS 9

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

UNIT - V MODAL ANALYSIS 9

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

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Understand the concept of State-State representation for Dynamic Systems.
2. Describe the solution techniques of state equations.
3. Realize the properties of control systems in state space form.
4. Identify non-linearities and evaluate the stability of the system using Lyapnov notion .
5. Perform Modal analysis and design controller and observer in state space form.

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-, 1999.
4. John J. D'Azzo, C. H. Houpis and S. N. Sheldon, "Linear Control System Analysis and Design with MATLAB", Taylor Francis, 2003.
5. M. Vidyasagar, "Nonlinear Systems Analysis', 2nd edition, Prentice Hall, Englewood Cliffs, New Jersey, 2002.
6. D. Roy Choudhury, "Modern Control Systems", New Age International, 2005.

CO - PO MAPPING

PS3164	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	-	2	2	3	-
CO2	2	2	3	-	2	3
CO3	3	-	3	-	-	-
CO4	3	-	3	2	2	-
CO5	3	-	3	2	3	2
Average	**2.8**	**2.0**	**2.8**	**2.0**	**2.5**	**2.5**

PS3165	RESTRUCTURED POWER SYSTEM	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. Describe the behavior of deregulated markets in power system.
2. Describe the technical and non-technical issues in deregulated power industry.
3. Identify the methods of Local Marginal prices calculation in transmission and the function of financial transmission rights.
4. Analyze the energy and ancillary services management in deregulated power industry.
5. Discriminate the restructuring framework US and Indian power sectors.

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 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

1. Ability to Describe the requirement for deregulation of the electricity market and the principles of market models in power systems.
2. Ability to Analyze the methods of congestion management in deregulated power system
3. Ability to Analyze the locational marginal pricing and financial transmission rights
4. Ability to Analyze the ancillary services management
5. Ability to Differentiate the framework of US and Indian power sectors.

REFERENCES

1. Mohammad Shahidehpour, Muwaffaq Alomoush, “Restructured electrical power systems: operation, trading and volatility” Marcel Dekker Pub.,2001.
2. Kankar Bhattacharya, Math H.J.Boolen, and Jaap E. Daadler, "Operation of restructured power systems”, Kluwer AcademicPub.,2001.
3. Paranjothi, S.R., “Modern Power Systems The Economics of Restructuring”, New Age International Publishers, First Edition: 2017.

4. Sally Hunt, Making competition work In electricity", John Willey and Sons Inc.2002.
5. Steven Stoft," Power System Economics: Designing Markets for Electricity",Wiley-IEEE Press, 2002.
6. A. Khaparde, A. R. Abhyankar, "Restructured Power Systems", NPTEL Course, https://nptel.ac.in/courses/108101005/.

CO - PO MAPPING

PS3165	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	1	2	3	-	-
CO2	3	1	2	3	-	-
CO3	3	1	2	3	-	-
CO4	3	1	2	3	-	-
CO5	3	1	2	3	-	-
Average	**3.0**	**1.0**	**2.0**	**3.0**	**-**	**-**

PRACTICAL

PS3166	POWER SYSTEM SIMULATION LABORATORY – I	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 planning, software packages.
- To apply iterative techniques for power flow analysis.
- To analyze power system security using shift factors.
- To analyze the overcurrent relay settings and their coordination.
- To do stability analysis on single machine and multi machine configuration.

LIST OF EXPERIMENTS

1 Power flow analysis by Newton-Raphson method and Fast decoupled method.

2 Transient stability analysis of single machine-infinite bus system using classical machine model.

3 Contingency analysis: Generator shift factors and line outage distribution factors

4 Economic dispatch using lambda-iteration method.

5 Unit commitment: Priority-list schemes and dynamic programming.

6 Design of State Estimation (DC).

7 Analysis of switching surge using EMTP: Energization of a long distributed-parameter Line.

8 Analysis of switching surge using EMTP : Computation of transient recovery voltage.

9 Simulation and Implementation of Voltage Source Inverter.

10 Digital Over Current Relay Setting and Relay Coordination using Suitable software packages.

11 Co-ordination of over-current and distance relays for radial line protection

TOTAL : 60 PERIODS

COURSE OUTCOMES

- Ability to analyze the power flow using Newton-Raphson method, Fast decoupled method and Ladder Iterative Technique.
- Able to perform contingency analysis & state estimation.
- Ability to select and coordinate over current relay.
- Acquired knowledge in steady state voltage stability.
- Acquired knowledge in over-current and distance relays.

LIST OF EQUIPMENTS FOR A BATCH OF 30 STUDENTS

1	Computers (Intel Core i3, 250 GB, 2 GB RAM)	18
2	Printer	01
3	Server (Intel Core i3, 4 GB RAM) (High Speed Processor)	01
4	Software: MATLAB / PSCAD / EUROSTAG / MIPOWER any Power system simulation software 5 user license.	5

CO - PO MAPPING

PS3166	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	1	-	-	1	-	1
CO2	1	2	1	2	2	1
CO3	1	2	-	2	2	1
CO4	1	2	2	2	-	-
CO5	1	-	1	2	2	2
Average	**1.0**	**2.0**	**1.33**	**1.8**	**2.0**	**1.25**

PS3167 POWER SYSTEM SIMULATION LABORATORY - II L T P C

0 0 4 2

COURSE OBJECTIVES

To impart knowledge on the following topics

1. To analyze the small signal stability for SMIB and multi machine system.
2. To apply iterative technique for power flow analysis with STATCOM.
3. To calculate Available Transfer Capability in power system network.
4. To study the characteristics of variable speed wind energy conversion system.
5. To analysis harmonics and design the filters for mitigation of harmonics.

LIST OF EXPERIMENTS

1. To analysis harmonics and design the filters for mitigation of harmonics.
2. Small-signal stability analysis of multi-machine configuration with classical machine model.
3. Induction motor starting analysis.
4. Transient analysis of two-bus system with STATCOM.
5. Available Transfer Capability calculation using an existing load flow program.
6. Study of variable speed wind energy conversion system- DFIG.
7. Study of variable speed wind energy conversion system- PMSG.
8. Computation of harmonic indices generated by a rectifier feeding a R-L load.
9. Design of active filter for mitigating harmonics.
10. Testing of Low impedance biased Current Differential protection with Simulation of excitation failure of generator by PSCAD/EMTDC.

LIST OF EQUIPMENTS FOR A BATCH OF 30 STUDENTS

1. Computers (Intel Core i3, 250 GB, 2 GB RAM) 18
2. Printer 1
3. Server (Intel Core i3, 4 GB RAM) (High Speed Processor) 1
4. Software: MATLAB / PSCAD / EUROSTAG / MIPOWER any Power system simulation software 5 userlic.,

TOTAL: 60 PERIODS

COURSE OUTCOMES

1. Ability to analyze the small signal stability of SMIB and Multi machine system.
2. Ability to analyze load flow and transient analysis of power system with STATCOM.
3. Ability to calculate Availability Transfer Capability in power system network.
4. Ability to analyze characteristics of variable speed wind energy conversion system.
5. Ability to analyze harmonics and design the filters for mitigation of harmonics.

REFERENCES

R1. Laboratory Manual prepared by Course Coordinator

CO - PO MAPPING

PS3167	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	-	3	-	3	3
CO2	3	2	3	2	2	3
CO3	3	-	3	-	3	3
CO4	3	-	3	-	2	1
CO5	3	-	3	2	2	3
Average	**3.0**	**2.0**	**3.0**	**2.0**	**2.4**	**2.6**

SEMESTER - II

PS3261	POWER SYSTEM DYNAMICS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To impart knowledge on mathematical modeling of a synchronous machine in detail.
2. To enable the students to develop the transfer function model for excitation and speed governing systems.
3. To offer an opportunity to innovate newer procedures and better methods for effective design.
4. To enable the students to model the single and multi-machine power systems with controllers for stability analysis
5. To provide knowledge on enhancing small signal stability concepts in power system.

UNIT - I SYNCHRONOUS MACHINE MODELLING 9

Physical description of a synchronous machine: armature and field structure - direct and quadrature axes- Mathematical Description: 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, Physical interpretation of dq0 transformation, Per Unit Representations: power invariant form of Park‟s transformation; Equivalent Circuits for direct and quadrature axes, Steady-state Analysis: Voltage, current and flux-linkage phasor relationships, Computation of steady-state values.

UNIT - II MODELLING OF EXCITATION AND SPEED GOVERNING SYSTEMS 9

Elements of an Excitation System: Types of Excitation System; Control and protective functions; Modeling of Excitation system components: Modeling of IEEE type ST1A (1992) excitation model, Turbine and Governing System Modeling: Classical transfer function of a hydraulic turbine (no derivation), Special characteristics of a hydraulic turbine, Electrical analogue of a hydraulic turbine, Governor for Hydraulic Turbine: Requirement for a transient droop, Block diagram of governor with transient droop compensation, Modeling of Single reheat tandem compounded type Steam Turbine.

UNIT - III SMALL-SIGNAL STABILITY ANALYSIS WITHOUT CONTROLLERS 9

Classification of Stability, Concepts of Stability of Dynamic Systems: State-space representation, Eigen properties of the state matrix: Eigen values and eigenvectors for stability, Participation factor, Single-Machine Infinite Bus (SMIB) Configuration: Classical Machine Model stability analysis with numerical example, Effects of Field Circuit Dynamics: Block diagram representation with K-constants; expression for K-constants (no derivation), effect of field flux variation on system stability.

UNIT - IV SMALL-SIGNAL STABILITY ANALYSIS WITH CONTROLLERS 9

Effects of Excitation System: Thyristor Excitation System with AVR, Block diagram representation with Exciter and AVR, Effect of AVR on Synchronizing and Damping torque components, Power System Stabilizer: Block diagram representation with AVR and PSS, System state matrix including PSS-Illustration of principle of PSS application with numerical example - Small Signal Stability of Multimachine systems: illustration of formation of system state matrix for a two-machine system with classical models for synchronous machines.

UNIT - V ENHANCEMENT OF SMALL SIGNAL STABILITY 9

Power System Stabilizer – Stabilizer based on shaft speed signal (delta omega) – Delta P-Omega Stabilizer-Frequency-based stabilizers – Digital Stabilizer – Excitation control design – Exciter gain – Phase lead compensation – Stabilizing signal washout and stabilizer gain – Stabilizer limits, Selection of PSS location.

TOTAL: 45 PERIODS

COURSE OUTCOMES

At the end of this course, learners will be able to:

1. Analyze the mathematical modeling and inductance calculations in a synchronous machine.
2. Develop the transfer function model for excitation, speed governing and turbine systems.

3. Analyze the small signal stability of SMIB power systems.
4. Analyze the small signal stability of SMIB and Multi-machine power systems with damping controllers.
5. Describe feedback controllers for small signal stability enhancement in power systems.

REFERENCES

1. Prabha Kundur, "Power System Stability and Control", Tata McGraw-Hill, 2014.
2. R.Ramanujam," Power System Dynamics: Analysis and Simulation, PHI Learning Private Limited, Second print, New Delhi, 2013.
3. J.Machowski, Bialek, Bumby, "Power System Dynamics and Stability", John Wiley and sons, 3rd Edition, 2020.
4. Vijay Vittal, James D. McCalley, P.M Anderson and A.A Fouad, "Power System Control and Stability", Iowa State University Press, Ames, Iowa, 3rd edition, 2019.
5. P. W. Sauer and M. A. Pai," Power System Dynamics and Stability", Stipes Publishing Co., 2007.

CO - PO MAPPING

PS3261	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	-	3	2	-	3
CO2	3	1	3	2	2	3
CO3	3	1	3	3	2	3
CO4	3	1	3	3	2	3
CO5	3	1	3	2	2	3
Average	**3.0**	**1.0**	**3.0**	**2.4**	**2.0**	**3.0**

PS3262	HVDC AND FACTS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To emphasis the need for FACTS controllers.
2. To learn modeling of series and shunt FACTScontrollers.
3. To analyze the interaction of different FACTS controller.
4. To impart knowledge on operation, modelling and control of HVDC link.
5. To perform steady state analysis of AC/DC system.

UNIT - I INTRODUCTION 9

Review of basics of power transmission networks-control of power flow in AC transmission line- Analysis of uncompensated AC Transmission line- Passive reactive power compensation:Effect of series and shunt compensation at the mid-point of the line on power transfer- Needfor FACTS controllers- types of FACTS controllers-Need for HVDC system- MTDC system Review of basics of LCC and VSC HVDC system. Configurations-Monopolar Asymmetric and Symmetric MMC-HVDC Scheme**-** Bipolar and Homopolar HVDC Scheme- Multi-Terminal HVDC Configuration- Layout of HVDC system (LCC, VSC).

UNIT - II THYRISTOR BASED FACTS CONTROLLERS 9

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

UNIT-III ANALYSIS OF LCC HVDC CONVERTERS AND HVDC SYSTEM CONTROL 9

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. Modelling of LCC HVDC system and controllers, transformer derating and core saturation instability, Concepts of Power Oscillation Damping Controller, Frequency Controller and Sub synchronous Damping controller in LCC HVDC.

UNIT-IV VOLTAGE SOURCE CONVERTER BASED FACTS CONTROLLERS 9

Static synchronous compensator (STATCOM) - Static synchronous series compensator (SSSC) Operation of STATCOM and SSSC-Power flow control with STATCOM and SSSC-Modelling of STATCOM and SSSC for power flow and transient stability studies –operation of Unified and Interline power flow controllers (UPFC) - Modelling of UPFC and IPFC for power flow and transient stability studies-Concepts of Power Oscillation Damping using FACTS controllers.

UNIT-V VOLTAGE SOURCE CONVERTER BASED HVDC SYSTEM AND CONTROL 9

Applications VSC based HVDC: Operation, Modelling for steady state and dynamic studies. Introduction to modular multilevel converters- main circuit design- converter operating Principle and Averaged Dynamic Model- Per-Phase Output-Current Control - Arm-Balancing (Internal) Control- Vector Output-Current Control-Higher-Level Control-Modulation and Submodule Energy Balancing- Offshore HVDC integration System Studies -Control and Protection of MMC-HVDC under AC and DC Network Fault Contingencies- Modeling and Simulation of MMC based MTDC Simulation exercises, Steady state, Fault recovery characteristics - Solution of DC load flow-Solution of AC-DC power flow: Sequential and Simultaneous methods.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Learners will be able to refresh on basics of power transmission.
2. Ability to design series and shunt compensating devices.
3. Ability to understand FACTS controllers.
4. Learners will attain knowledge on HVDC Link.
5. Learners will able to explore MMC converter applications FACTS and MTDC systems

REFERENCES

1. Mohan Mathur, R., Rajiv. K. Varma, "Thyristor – Based Facts Controllers for Electrical Transmission Systems", IEEE press and John Wiley & Sons, Inc. 2012.
2. K.R.Padiyar, "HVDC Power Transmission Systems", Third edition, New Age International (P) Ltd., New Delhi, 2017.
3. K.R.Padiyar, "FACTS Controllers in Power Transmission and Distribution", Second Edition, New Age International(P) Ltd., Publishers, New Delhi, 2016.
4. J.Arrillaga, "High Voltage Direct Current Transmission", Peter Pregrinus, London, 1998.

CO - PO MAPPING

PS3262	PROGRAM OUTCOMES					
	1	2	3	4	5	6
CO1	1	-	3	2	-	3
CO2	3	1	3	2	2	3
CO3	3	1	3	3	2	3
CO4	3	2	3	3	2	3
CO5	3	2	3	2	2	3
Average	2.6	1.2	3.0	2.4	2.0	3.0

PS3263	ADVANCED POWER SYSTEM PROTECTION	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To demonstrate the basic concepts and recent trends in power system protection.
2. To design and work with the concepts of digital and numerical relaying of various power apparatuses.
3. To train up with the relay coordination for the transmission line protection schemes.
4. To expose PC applications for designing protective relaying schemes.
5. To compare different protection schemes of a power apparatus through performance analysis.

UNIT - I NUMERICAL PROTECTION 9

Introduction - Block diagram of numerical relay - Sampling theorem - Correlation with a reference wave - Least Error Squared (LES) technique - Digital filtering and numerical over - Current Protection - Numerical transformer differential protection- Numerical distance protection of transmission line.

UNIT - II DIGITAL PROTECTION OF TRANSMISSION LINE 9

Introduction - Protection scheme of transmission line – Distance relays - Traveling wave relays - Digital protection scheme based upon fundamental signal - Hardware design - Software design - Digital protection of EHV/UHV transmission line based upon traveling wave phenomenon - new relaying scheme using amplitude comparison.

UNIT - III DIGITAL PROTECTION OF SYNCHRONOUS GENERATOR & TRANSFORMER 9

Introduction - Faults in synchronous generator - Protection schemes for Synchronous Generator - Digital protection of Synchronous Generator - Faults in a Transformer - Schemes used for Transformer Protection - Digital Protection of Transformer.

UNIT - IV DISTANCE AND OVERCURRENT RELAY SETTING AND CO-ORDINATION 9

Directional instantaneous IDMT over current relay - Directional multi-Zone distance relay - Distance relay setting - Co-ordination of distance relays - Co-ordination of over current relays - Computer graphics display - Man-machine interface subsystem - Integrated operation of national power system - Application of computer graphics.

UNIT - V PC APPLICATIONS FOR DESIGNING PROTECTIVE RELAYING SCHEME 9

Types of faults – Assumptions - Development of algorithm for SC studies - PC based integrated software for SC studies - Transformation to component quantities - SC studies of multiphase systems Ultra-high-speed protective relays for high voltage long transmission line.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Familiarize the underlying principle of digital techniques for power system protection.
2. Design the relaying scheme for protection of power apparatus using digital techniques.
3. Evaluate and interpret relay coordination.
4. Develop PC based algorithm for short circuit studies.
5. Compare the performance of modern protection schemes with the conventional schemes.

REFERENCES

1. L.P.Singh,"Digital Protection – Protective Relaying from Electromechanical to Microprocessor", New Age International Ltd., New Delhi, Second Edition, 2006.
2. S. R. Bhide, “Digital Power System Protection”, Prentice Hall of India Pvt. Ltd., New Delhi, 2014.
3. Paithankar and Bhide, “Fundamentals of Power System Protection”, Prentice Hall of India Pvt. Ltd., New Delhi, Second edition, 2010.

4. Paithankar, “Transmission Network Protection”, Marcel & Dekker, New York, 1998.
5. Stanley Horowitz, “Protective Relaying for Power System II”, John Wiley & Sons, 2008.
6. T. S. M. Rao, “Digital / Numerical relays”, Tata McGraw Hill, New Delhi, 2005.

CO - PO MAPPING

PS3263	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	2	2	2	2	2	1
CO2	2	2	2	3	3	2
CO3	2	3	2	2	2	1
CO4	1	2	3	3	2	2
CO5	2	3	3	3	2	1
Average	**1.8**	**2.4**	**2.4**	**2.6**	**2.2**	**1.4**

PRACTICAL

PS3264 ADVANCED POWER SYSTEM SIMULATION LABORATORY

L	T	P	C
0	0	4	2

COURSE OBJECTIVES

1. To impart knowledge on the following topics
2. Study the performance of various renewable energy sources.
3. Obtain hands-on experience on Solar PV system.
4. Analyze the grid integration issues of renewable energy sources.
5. To analyze the performance characteristics of DFIG and PMSG.

LIST OF EXPERIMENTS

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.

10 Modeling of Active power filter for power system.

TOTAL: 60 PERIODS

COURSE OUTCOMES

- Students will understand the characteristics of various renewable energy sources through modeling.
- Students will be able to model the different MPPT algorithm and understand their merits and demerits
- Students will learn modeling and control of DFIG and PMSG.
- Students will design and model PV system integration with grid.

LIST OF EQUIPMENTS FOR A BATCH OF 18 STUDENTS

1	25 Nos of PC loaded with PSCAD/EMTDC Software Package	25 Users
2	Laser Printer	1

CO - PO MAPPING

PS3264	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	2	1	3	2	-	3
CO2	2	1	3	2	2	3
CO3	2	1	3	2	2	3
CO4	2	2	3	2	2	3
CO5	2	2	3	2	2	3
Average	**2.0**	**1.4**	**3.0**	**2.0**	**2.0**	**3.0**

PS3241	MINI PROJECT	L	T	P	C
		0	0	4	2

COURSE OBJECTIVES

To impart knowledge on the following topics

1. To develop the ability to solve a specific problem in the domain based on their interest.
2. To acquire knowledge and idea in the particular domain by the literature review.
3. To find the successful solution of the problem identified.
4. To demonstrate the implemented project.
5. To prepare the documentation and present the model effectively to reach the social people.

COURSE DESCRIPTION

The students in a group of 3 to 4 works on a topic approved by the head of the department under the guidance of a faculty member and prepares a comprehensive project report after completing the work to the satisfaction of the supervisor. The progress of the project is evaluated based on a minimum of three reviews. The review committee may be constituted by the Head of the Department. A project report is required at the end of the semester. The project work is evaluated based on oral presentation and the project report jointly by external and internal examiners constituted by the Head of the Department.

TOTAL: 60 PERIODS

COURSE OUTCOMES

At the end of this course, learners will be able to:

1. Frame the problem solution
2. Explore the knowledge in the corresponding field of project.
3. Compare the model with the existing system.
4. Demonstrate the model designed for the solution.
5. Publish the results obtained from the model.

CO - PO MAPPING

PS3241	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	2	3	2	2	2
CO2	3	2	3	2	2	2
CO3	3	2	3	2	2	2
CO4	3	2	3	2	2	2
CO5	3	2	3	2	2	2
Average	**3.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**

SEMESTER – III

BA3371	RESEARCH METHODOLOGY AND IPR	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To familiarise the students with the scientific methodology involved in research process.
2. To help students to understand various concepts related to Research design and measurement.
3. To learn to design and validate data collection tools.
4. To give an idea about IPR, registration and its enforcement.
5. To acquaint the students with basics of intellectual property rights

UNIT - I	INTRODUCTION TO RESEARCH AND ITS DESIGN	9

The concept of research – Characteristics of good research – The hallmarks of scientific research – Building blocks of science in research – Concept of applied and Basic research – Quantitative and Qualitative Research techniques – Need for theoretical frame work – Hypothesis development and testing. Research design – Purpose of the study: Exploratory, Descriptive, Experimental Research Design, Hypothesis Testing, Measurement of variables - Scales and measurements of variables - Factorial Design in Research – Taguchi method in Research, Developing scales.

UNIT - II	DATA COLLECTION METHODS AND ANALYSIS TECHNIQUES	9

Types of data – Primary Vs secondary data, Advantages and Disadvantages of various Data-Collection Methods, Sampling plan - Sampling Techniques – Probability and non-probability Sampling, Determination of Optimal sample size, Data Analysis – Factor Analysis – Cluster Analysis – Discriminant Analysis – Multiple Regression and Correlation – Canonical Correlation – Application of Statistical (SPSS) Software Package in Research.

UNIT - III	REPORT WRITING AND CODE OF ETHICS FOR RESEARCH	9
Research report – Different types – Contents of report –Report format – Title of the report – Report Presentation – Proposal- purpose, Topic selection, types and structure – Recommendations and implementation section – Conclusions and Scope for future work - Ethics in research – Ethical behaviour of research– subjectivity and objectivity in research - ethical issues relating to the researcher.		
UNIT - IV	**INTELLECTUAL PROPERTY RIGHTS**	**9**
Nature of Intellectual Property - Patents, Designs, Trade mark and Copyright. Process of Patenting and Development: technological research, innovation, patenting & development. Procedure for grants of patents, Patenting under PCT.		
UNIT - V	**INTELLECTUAL PATENT RIGHTS AND NEW DEVELOPMENT**	**9**
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		
		TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Understand research problem and analyse different research techniques.
2. Develop survey instrument and use appropriate data collection method and use appropriate statistical techniques for data analysis
3. Prepare a detailed research report with the required details and follow research ethics.
4. Explain the ethical principles to be followed while patenting or obtaining copyright.
5. Apply for patent rights and demonstrate New developments in IPR

TEXT BOOKS :

1. C.R. Kothari, “Research Methodology Methods & Techniques”, Second Edition, New Delhi: New Age International Publisher, 4th edition 2019.
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1. Donald H. McBunny, Research Methods, Thomson Asia Pvt. Ltd. Singapore, 7th edition 2006.
2. Ranjit Kumar, “Research Methodology – A Step by Step for Beginner’s”, 2nd Edition, Pearson Education, 2016
3. Donald R. Cooper and Ramela S. Schindler, Business Research Methods, Tata McGraw – Hill Publishing Company Limited, New Delhi, 12th Edition 2013
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6. Raymond-Alain Thie’tart, et. Al., Doing Management Research, Sage Publications, London, 1999.
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PS3341	TECHNICAL SEMINAR	L	T	P	C
		0	0	2	1

COURSE OBJECTIVES

To impart knowledge on the following topics

1. To encourage the students to study advanced engineering developments.
2. To prepare and present technical reports.
3. To encourage the students to use various teaching aids such as power point presentation and demonstrative models.
4. To prepare the students in preparing project reports and to face an interview.
5. To encourage the students to present the technical topics

METHOD OF EVALUATION

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

TOTAL: 30 PERIODS

COURSE OUTCOMES

At the end of this course, learners will be able to:

1. Ability to study advanced engineering developments
2. Ability to prepare and present technical reports.
3. Ability to use various teaching aids such as power point presentation and demonstrative models.
4. Ability to prepare project reports and to face an interview.
5. Ability to prepare the students to present the technical topics

CO - PO MAPPING

PS3341	PROGRAM OUTCOMES					
	1	2	3	4	5	6
CO1	3	2	-	-	-	-
CO2	3	2	-	-	-	-
CO3	3	2	-	-	-	-
CO4	3	2	-	-	-	-
CO5	3	2	-	-	-	-
Average	**3.0**	**2.0**	**-**	**-**	**-**	**-**

PS3342	INTERNSHIP	L	T	P	C
		0	0	0	2

COURSE OBJECTIVES

1. Analyze a professional setting's strength and challenges.
2. Communicate in a workplace environment in a clear and confident manner.
3. Evaluate performance and accept feedback, in order to make changes as necessary.
4. Articulate their experience and skills to potential employers.
5. Identify and articulate next steps in their career trajectory.

COURSE DESCRIPTION

The students may be allowed to arrange internship. In that case a student can take a letter from the placement/respective department and contact the company. The confirmation letter from the company has to be submitted in the placement / respective department. Students will be associated with one faculty from respective department who will act as internal mentor. During six months duration, internal mentor will assess the student's performance twice. Final Evaluation of internship will be done jointly by the internal and company mentor. Students will maintain the record of the work done in the industry and submit a report in the institute within one week of the start of the next semester. The certificate and the report have to be duly signed by a responsible official of the company. The institute will arrange evaluation of the internship within 15 days of the start of the semester. The date of evaluation will be notified at least one week before the date of evaluation

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Apply knowledge, skills, and experience to a work environment.
2. Acquire new learning through challenging and meaningful activities.
3. Build and maintain strong networking/mentoring relationships.
4. Identify, clarify and/or confirm professional direction as it relates to the academic studies and future career path.
5. Develop self-understanding, self-discipline, maturity and confidence.

CO - PO MAPPING

PS3342	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	2	1	1	1	2	2
CO2	2	1	1	1	2	2
CO3	2	-	-	-	2	2
CO4	2	-	-	-	2	2
CO5	2	-	-	-	2	2
Average	**2.0**	**1.0**	**1.0**	**1.0**	**2.0**	**2.0**

PS3343	PROJECT WORK PHASE - I	L	T	P	C
		0	0	12	6

COURSE OBJECTIVES

1. To enable a student to do an individual project work which may involve design, modelling, simulation and/or fabrication.
2. To analyze a problem both theoretically and practically.
3. To motivate the students to involve in research activities leading to innovative solutions for industrial and societal problem.
4. To train the students in preparing project reports and to face reviews and viva voce examination.
5. To present the work in International/National conference or reputed journals.

The student works on a topic approved by the head of the department under the guidance of a faculty member and prepares a comprehensive project report after completing the work to the satisfaction of the supervisor. The progress of the project is evaluated based on a minimum of three reviews. The review committee may be constituted by the Head of the Department. A project report is required at the end of the semester. The project work is evaluated based on oral presentation and the project report jointly by external and internal examiners constituted by the Head of the Department.

TOTAL: 180 PERIODS

COURSE OUTCOMES

1. Comprehend a problem thoroughly and provide an appropriate solution.
2. Do a systematic literature survey.
3. Derive a mathematical model for the system under study.
4. Get proficiency over the software used for simulation and analysis.
5. Able to design hardware model.
6. Present the findings of a research work in conferences and publish in journals

CO - PO MAPPING

PS3343	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	1	3	2	1	1
CO2	3	3	3	1	2	1
CO3	3	1	3	3	2	3
CO4	3	3	3	2	2	2
CO5	3	2	3	3	2	2
Average	**3.0**	**2.0**	**3.0**	**2.4**	**1.8**	**1.8**

SEMESTER - IV

PS3441	PROJECT WORK PHASE - II	L	T	P	C
		0	0	24	12

COURSE OBJECTIVES

1. To enable a student to do an individual project work which may involve design, modelling, simulation and/or fabrication.
2. To analyze a problem both theoretically and practically.
3. To motivate the students to involve in research activities leading to innovative solutions for industrial and societal problem
4. To train the students in preparing project reports and to face reviews and viva voce examination.
5. To present the work in International/National conference or reputed journals

The student works on a topic approved by the head of the department under the guidance of a faculty member and prepares a comprehensive project report after completing the work to the satisfaction of the supervisor. The progress of the project is evaluated based on a minimum of three reviews. The review committee may be constituted by the Head of the Department. A project report is required at the end of the semester. The project work is evaluated based on oral presentation and the project report jointly by external and internal examiners constituted by the Head of the Department.

TOTAL: 360 PERIODS

COURSE OUTCOMES

1. Ability to comprehend a problem thoroughly and provide an appropriate solution.
2. Ability to do a systematic literature survey.
3. Ability to derive a mathematical model for the system under study.
4. Ability to get proficiency over the software used for simulation and analysis.
5. Ability to present the findings of a research work in conferences and publish in journals

CO - PO MAPPING

PS3441	PROGRAM OUTCOMES					
	1	2	3	4	5	6
CO1	3	-	1	1	1	1
CO2	3	3	-	1	-	-
CO3	3	-	2	3	1	1
CO4	3	-	2	2	1	1
CO5	3	-	-	-	-	-
Average	**3.0**	**3.0**	**1.6**	**1.8**	**1.0**	**1.0**

PROFESSIONAL ELECTIVE COURSES

PROFESSIONAL ELECTIVE I

PPS101	POWER SYSTEM STATE ESTIMATION AND SECURITY ASSESSMENT	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To introduce the state estimation on DC network.
2. To impart in-depth knowledge on power system state estimation.
3. To study alternative formulations of WLS state estimation.
4. To get insight of network observability and bad data identification.
5. To gain knowledge on Power System Security Assessment.

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 AND BAD DATA DETECTION IDENTIFICATION 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. 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.

UNIT - V POWER SYSTEM SECURITY ASSESSMENT 9

Introduction to Security Assessment -Static Security Assessment-Summary of Different Types of Static Security Indices-Methods for Assessing Power System Security-Methods for Assessing Power System Security-Dynamic Security Assessment-Future Trends to Assessing Dynamic Security-Issues Related to Integration of Renewable Energies-Security Enhancement-Issues and Methods to Solve SCOPF Problem-Deal with the Challenges for Enhancing Dynamic Security.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Ability to define various concepts implied in state estimation and its need in dc networks.
2. Ability to apply state estimation algorithms in modelling of transmission lines.
3. Ability to compare the different types of formulation techniques of state estimation.

4. Ability to analyze network observability and identify the bad data detection using different methods.
5. Ability to list the different types of assessing power system security and solve the issues.

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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4. Mukhtar Ahmad, "Power System State Estimation", Lap Lambert Acad Publishers,2013.
5. Felix L. Chernousko, " State Estimation for Dynamic Systems", CRC Press, 1993
6. Naim Logic, "Power System State Estimation" , LAP Lambert Acad. Publ., 2010.
7. Power System Security Assessment and Enhancement: A Bibliographical Survey.

CO - PO and CO - PSO MAPPING

PPS101	PROGRAM OUTCOMES					
	1	2	3	4	5	6
CO1	1	-	-	1	-	-
CO2	1	1	1	1	-	-
CO3	1	2	-	1	-	-
CO4	1	1	1	1	1	2
CO5	1	-	1	1	1	1
Average	1.0	1.3	1.0	1.0	1.0	1.5

PPS102	OPTIMIZATION TECHNIQUES TO POWER SYSTEM ENGINEERING	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To discriminate the capabilities of bio-inspired system and conventional methods in solving optimization problems
2. To examine the importance of exploration and exploitation swarm intelligent system to attain near global optimal solution
3. To distinguish the functioning of various swarm intelligent systems
4. To employ various bio-inspired algorithms for Power systems engineering applications.
5. understand and implement the multi-objective optimization techniques to implement in power system problems

UNIT - I FUNDAMENTALS OF SOFT COMPUTING TECHNIQUES 9

Definition-Classification of optimization problems - Unconstrained and Constrained optimization Optimality conditions - Introduction to intelligent systems - Soft computing techniques - Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Single solution based and population based algorithms – Exploitation and exploration in population based algorithms - Properties of Swarm intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi-objective problems.

UNIT - II GENETIC ALGORITHM AND PARTICLE SWARM OPTIMIZATION 9

Genetic algorithms - Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators - different types of crossover and mutation operators - Bird flocking and Fish Schooling – anatomy of a particle - equations based on velocity and positions - PSO topologies - control parameters – GA and PSO algorithms for solving ELD problem.

UNIT - III ANT COLONY OPTIMIZATION and ARTIFICIAL BEE COLONY ALGORITHMS 9

Biological ant colony system - Artificial ants and assumptions - Stigmergic communications - Pheromone updating - local-global - Pheromone evaporation - ant colony system- ACO Models Touring ant colony system -max min ant system - Concept of elistic Ants - Task partitioning in honey bees - Balancing foragers and receivers - Artificial bee colony (ABC) algorithms - binary ABC algorithms – ACO and ABC algorithms for solving Economic Dispatch of thermal units.

UNIT - IV SHUFFLED FROG-LEAPING ALGORITHM and BAT OPTIMIZATION ALGORITHM 9

Bat Algorithm - Echolocation of bats - Behavior of microbats - Acoustics of Echolocation - Movement of Virtual Bats - Loudness and Pulse Emission - Shuffled frog algorithm - virtual population of frogs - comparison of memes and genes - memeplex formation - memeplexupdation - BA and SFLA algorithms for solving ELD and optimal placement and sizing of the DG problem.

UNIT - V MULTI OBJECTIVE OPTIMIZATION 9

Multi-Objective Optimization Introduction - Concept of Pareto optimality - Non-dominant sorting Technique - Pareto fronts-best compromise solution - min-max method-NSGA-II algorithm and applications to power systems.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Ability to understand the capabilities of bio-inspired system and conventional methods in solving optimization problems
2. Ability to understand and implement the ant colony algorithm and artificial bee colony algorithms to PS problems
3. Ability to implement the genetic algorithm and particle swarm optimization technique to solve the ED problems.
4. Ability to implement the shuffled frog-leaping algorithm and bat optimization algorithm for solving ELD and optimal placement and sizing of the DG problem.
5. Ability to understand and implement the multi-objective optimization techniques to implement in power system problems.

REFERENCES

1. Xin-She Yang, “Recent Advances in Swarm Intelligence and EvolutionaryComputation”, Springer International Publishing, Switzerland, 2015.
2. Kalyanmoy Deb, “Multi-Objective Optimization using Evolutionary Algorithms”, John Wiley & Sons, 2001.
3. James Kennedy and Russel E Eberheart, “Swarm Intelligence”, the Morgan Kaufmann Series in Evolutionary Computation, 2001.
4. Eric Bonabeau, Marco Dorigo and Guy Theraulaz, “Swarm Intelligence-From natural to Artificial Systems”, Oxford university Press, 1999.
5. David Goldberg, “Genetic Algorithms in Search, Optimization and Machine Learning”, Pearson Education, 2007.
6. Konstantinos E. Parsopoulos and Michael N. Vrahatis, “Particle Swarm Optimization and Intelligence: Advances and Applications”, Information science reference, IGI Global, 2010.
7. N P Padhy, “Artificial Intelligence and Intelligent Systems”, Oxford University Press, 2005.
8. D.P. Kothari, J.S. Dhillon, “Power System Optimization”, PHI, 2nd edition, 30 December 2010.

CO - PO MAPPING

PPS102	**PROGRAM OUTCOMES**					
	1	**2**	**3**	**4**	**5**	**6**
CO1	2	-	-	1	-	-
CO2	2	-	-	1	-	-
CO3	2	-	-	1	-	-
CO4	2	-	-	1	-	-
CO5	2	-	-	1	-	-
Average	**2.0**	**-**	**-**	**1.0**	**-**	**-**

PPS103	COMPUTATIONAL INTELLIGENCE TECHNIQUES TO POWER SYSTEMS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. Various optimization techniques and need of Optimal Control.
2. Identify the Linear Quadratic Tracking Problems and Numerical Techniques For Optimal Control.
3. Concepts of Model Decomposition and Convolutional Neural Network.
4. Application of Filtering and Estimation techniques for power system applications.
5. Use of Kalman filter for power system protection application.

UNIT - I INTRODUCTION 9

Application of genetic algorithm to power system load forecasting, participle swam optimization for reactive power optimization, Optimization Techniques for emission dispatch of power plant, Differential Evolution Algorithm, Optimization Techniques for pole placement and state feedback algorithms, –Problem formulation and forms of optimal Control– Selection of performance measures. Necessary conditions for optimal control – State inequality constraints – Minimum time problem.

UNIT - II LINEAR QUADRATIC TRACKING PROBLEMS AND NUMERICAL TECHNIQUES FOR OPTIMAL CONTROL 9

Linear tracking problem – LQG problem –Principle of Optimality – Significance and difficulties - Computational procedure for solving optimal control problems – Characteristics of dynamic programming solution – Dynamic programming application to discrete and continuous systems – Hamilton Jacobi Bellman equation. 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 - III MODEL DECOMPOSITION AND CONVOLUTIONAL NEURAL NETWORK 9

CNN Classification, CNN Algorithm ,model decomposition techniques, application of model decomposition and CNN based techniques for various power system fault digonesis problems, model predictive controllers for power system for power system stabilizers.

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 estimation Least square estimation –Recursive estimation

UNIT - V KALMAN FILTER 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, Application of Kalman filter for power system protection applications.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Understand the concept of Optimization Technique for power system.
2. Identify, Formulate and measure the performance of Optimal Controllers for power system
3. Understand Model Decomposition And Convolutional Neural Network
4. Apply Filtering and Estimation techniques for power system applications.
5. Design Kalman filter for power system protection application.

REFERENCES

1. Ajith Abraham and Swagatham Das.,"Computaional Intelligence in Power Engineering", Springer Verlag.,2010.

3. Yong Hua Song, Johns Allen, Aggarwal Raj, 'Computational Intelligence Application to Power System', Springer Netherlands., 1997.

CO - PO MAPPING

PPS103	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	1	2	1	-	1	-
CO2	2	3	3	-	2	-
CO3	2	-	3	1	3	2
CO4	3	2	1	2	-	1
CO5	2	2	2	-	3	-
Average	**2.0**	**2.25**	**2.0**	**1.5**	**2.66**	**1.5**

PPS104	IoT FOR SMART SYSTEMS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To study about Internet of Things technologies and its role in real time applications.
2. To introduce the infrastructure required for IoT.
3. To familiarize the accessories and communication techniques for IoT.
4. To provide insight about the embedded processor and sensors required for IoT
5. To familiarize the different platforms and Attributes for IoT.

UNIT - I INTRODUCTION TO INTERNET OF THINGS 9

Overview, Hardware and software requirements for IOT, Functional Blocks of an IoT Ecosystem - Sensor and actuators, Technology drivers, Business drivers, Typical IoT applications, Trends and implications.

UNIT - II IOT ARCHITECTURE 9

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

UNIT - III PROTOCOLS AND WIRELESS TECHNOLOGIES FOR IOT PROTOCOLS 9

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

Wireless technologies for IoT: WiFi (IEEE 802.11), Bluetooth/Bluetooth Smart, ZigBee/ZigBee Smart, UWB (IEEE 802.15.4), 6LoWPAN, Proprietary systems-Recent trends.

UNIT - IV IOT PROCESSORS 9

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

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

UNIT - V CASE STUDIES 9

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

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Analyze the concepts of IoT and its present developments.
2. Compare and contrast different platforms and infrastructures available for IoT
3. Explain different protocols and communication technologies used in IoT.
4. Analyze the big data analytic and programming of IoT.
5. Implement IoT solutions for smart applications.

REFERENCES

1. ArshdeepBahga and VijaiMadisetti : A Hands-on Approach "Internet of Things",Universities Press 2015
2. Oliver Hersent , David Boswarthick and Omar Elloumi " The Internet of Things", Wiley,2016.
3. Samuel Greengard, " The Internet of Things", The MIT press, 2015.
4. Adrian McEwen and Hakim Cassimally"Designing the Internet of Things "Wiley,2014.
5 Jean- Philippe Vasseur, Adam Dunkels, "Interconnecting Smart Objects with IP: The Next Internet" Morgan Kuffmann Publishers, 2010.

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CO - PO MAPPING

PPS104	PROGRAM OUTCOMES					
	1	2	3	4	5	6
CO1	1	2	1	-	-	-
CO2	-	2	-	-	-	-
CO3	1	2	-	1	3	-
CO4	2	-	3	3	3	3
CO5	3	2	3	3	3	3
Average	1.75	2.0	2.3	2.3	3.0	3.0

PPS105	RENEWABLE ENERGY AND GRID INTEGRATION	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To provide knowledge about the stand alone and grid connected renewable energy systems.
2. To equip with required skills to derive the criteria for the design of power converters for renewable energy applications.
3. To analyze and comprehend the various operating modes of wind electrical generators and solar energy systems.
4. To design different power converters namely AC to DC, DC to DC and AC to AC converters for renewable energy systems.
5. 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 penetration to grid. Grid Codes in India and other countries. Basic power electronic converters for renewable energy integration to grid-Qualitative analysis -Boost and buck-boost converters, three phase AC voltage controllers-AC-DC-AC converters, PWM Inverters, Grid Interactive Inverters-matrix converters.

UNIT - II 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 - III 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 - IV MPPT TECHNIQUES IN SOLAR AND WIND SYSTEMS 9

Case studies of PV-Maximum Power Point Tracking (MPPT) and Wind Energy system

UNIT - V HYBRID STORAGE SYSTEMS AND GRID MANAGEMENT 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)

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Ability to relate the power generation of different renewable energy sources to grid impact and grid codes.
2. Ability to explain the design principles of solar energy management systems.
3. Ability to understand the power conversion system of wind generators.
4 Ability to analyze the different Maximum Power Point tracking Techniques.
5 Ability to build grid connected and standalone renewable energy management system.

REFERENCES

1. H.S. Kalsi, 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.

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4. Rai. G.D, “Non-conventional energy sources”, Khanna publishes, 1993
5. Gray, L. Johnson, “Wind energy system”, prentice hall Iinc, 1995 6. Non-conventional Energy sources B.H.Khan Tata McGraw-hill Publishing Company, New Delhi.

CO - PO and CO - PSO MAPPING

PPS105	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	1	2	1	-	1	-
CO2	1	1	2	-	1	-
CO3	2	-	1	1	1	2
CO4	1	2	1	2	-	2
CO5	3	3	2	-	2	-
Average	**1.6**	**2.0**	**1.4**	**1.5**	**1.25**	**2.0**

PROFESSIONAL ELECTIVE - II

PPS201	ELECTRICAL POWER DISTRIBUTION SYSTEM	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To detail the function of electric power distribution network.
2. To derive the voltage profile enhancement and protection schemes.
3. To evaluate the reliability of the electrical distribution system.
4. To detail the automation schemes in various sections like substation, feeder, etc.,
5. To acquire wide knowledge in distribution system operation, protection, control, and expansion planning of distribution system architecture.

UNIT - I DISTRIBUTION SYSTEMS 9

Distribution systems: Types of distribution systems - Section and size of feeders – Primary and secondary distribution – Distribution substations – Effect of working voltage on the size of feeders and distributors – Effect of system voltage on economy – Voltage drop and efficiency of transmission - Qualitative treatment of rural distribution and industrial distribution.

UNIT - II CONTROL AND PROTECTION 9

Voltage control: Application of shunt capacitance for loss reduction – Harmonics in the system – Static VAR systems – Voltage profile enhancement schemes. System protection: Fuses and section analyzers - Over current protection - Under voltage and under frequency protection – Coordination of protective device.

UNIT - III RELIABILITY ANALYSIS 9

Primary and secondary system design considerations - Primary circuit configurations - Primary feeder loading - Secondary networks design- Economic design -Unbalance loads and voltage considerations.

UNIT - IV DISTRIBUTION AUTOMATION 9

Definitions – Automation switching control – Management information systems (MIS) – Remote terminal units – Communication methods for data transfer – Consumer information service (CIS) – Graphical information systems (GIS) - Automatic meter reading (AMR) – Remote control load management. Substation automation – Requirements – Control aspects in substations – Feeder automation – Consumer side automation.

UNIT - V EXPANSION PLANNING 9

Distribution system planning: Short term planning - Long term planning - dynamic planning - Sub- transmission and substation design. Sub-transmission networks configurations - Substation bus schemes - Distribution substations ratings - Service areas calculations. Distribution system expansion: Planning – Load characteristics – Load forecasting – Design concepts – Optimal location of substation – Design of radial lines – Solution technique.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Obtain fundamental knowledge in electric power distribution system.
2. Be proficient in control and protection schemes for distribution systems.
3. Gain familiarity to evaluate reliability of distribution systems.
4. Demonstrate the methodologies for distribution automation.
5. Able to develop strategies for expanding the existing distribution systems.

REFERENCES

1. C.L. Wadhwa, “Electrical Power Systems”, New Age International Publishers, Sixth Edition, 2014.
2. A.S. Pabla, “Electrical Power Distribution Systems”, Tata McGraw Hill Books Company, Sixth Edition, 2011.
3. V. Kamaraju, “Electrical Power Distribution Systems”, Tata McGraw Hill Books Company, Sixth Edition, 2009.
4. Anthony J. Pansini, “Electrical Distribution Engineering”, CRC Press, 2005.

5. H Lee Willis, “Distributed Power Generation Planning and Evaluation”, CRC Press, 2000.

6. James J. Burke, “Power distribution engineering: fundamentals and applications”, CRC Press, 2004.

7. James A Momoh, “Electric Power Distribution Automation Protection and Control” CRC Press, 2007.

CO - PO MAPPING

PPS201	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	1	-	-	-	2	1
CO2	2	2	2	1	3	2
CO3	2	2	3	1	2	2
CO4	2	2	3	1	3	2
CO5	3	3	2	2	2	2
Average	**2.0**	**1.8**	**2.0**	**1.0**	**2.4**	**1.8**

PPS202	WIND AND SOLAR ENERGY SYSTEMS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To study the concepts of wind energy system.
2. To understand the new developments in solar energy system.
3. To provide students with a solid foundation in mathematical, scientific, and engineering fundamentals required to solve wind and solar energy problems.
4. To acquire knowledge of grid integration techniques, and power quality issues of photo voltaic energy conversion system.
5. To understand the new technology & techniques in variety of applications in wind energy system and solar energy system.

UNIT - I WIND ENERGY CONVERSION 9

Wind resources – Nature and occurrence of wind – Power in the wind – Wind characteristics – Principles of wind energy conversions – Components of wind energy conversion system (WECS) – Classification of WECS – Advantages and disadvantages of WECS.

UNIT - II WIND ELECTRIC GENERATORS 9

Characteristics of Induction generators – Permanent magnet generators – Single phase operation of induction generators – Doubly fed generators – Grid connected and standalone systems – Controllers for wind driven self-excited systems and capacitor excited isolated systems – Synchronized operation with grid supply – Real and reactive power control.

UNIT - III PHOTO VOLTAIC MODELS 9

Solar cells and panels – Structure of PV cells – Semiconductor materials for PV cells – I-V characteristics of PV systems – PV models and equivalent circuits- Effects of irradiance and temperature on PV characteristics.

UNIT - IV PHOTO VOLTAIC ENERGY CONVERSION SYSTEM 9

Basic photo voltaic system for power generation – Advantages and disadvantages of photo voltaic solar energy conversion –Application of solar photo voltaic system – Components of PV systems- Design of PV systems- Power conditioning and storage arrangement – Maximum power point tracking (MPPT) - Introduction to string inverters.

UNIT - V RECENT ADVANCEMENTS IN WIND AND PV SYSTEMS 9

Wind farms and grid connections – Grid related problems on absorption of wind – Grid interfacing arrangement – Operation, control and technical issues of wind generated electrical energy – Interconnected operation – Hybrid systems. Recent Advances in PV Applications: Building Integrated PV systems, Grid Connected PV systems, Hybrid systems, Solar cars, Solar energy storage system and their economic aspects.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Understand the basics of wind energy conversion systems & solar energy conversion systems.
2. Implement the appropriate power extraction techniques.
3. Apply power electronics to the renewable energy systems.
4. Understand the grid integration techniques, and power quality issues.
5. Apply the technology & techniques in variety of applications.

REFERENCES

1. G.N. Tiwari, "Solar Energy: Fundamentals, Design, Modeling & Application", Narosa Publishing House, 2013.
2. G.D. Rai, "Non-conventional Energy Resources", Sixth Ed., Khanna Publishers, 2018.
3. B.H. Khan, "Non-conventional Energy Resources", Tata McGraw Hill Education India Pvt. Ltd., Third Edition, 2017.

4. D.P.Kothari and K.C.Singhal," Renewable Energy Sources and Emerging Technologies", P.H.I. 2nd Ed., 2011.

5. D.S.Chauhan, S.K. Srivastava, "Non – Conventional Energy Resources", 3rd Ed.,New Age Publishers, 2012.

6. Ashish Chandra and Taru Chandra, Non-conventional Energy Resources, 2ndEdn., Khanna Publishers, 2021.

CO - PO MAPPING

PPS202	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	1	1	-	-	2	-
CO2	3	1	3	-	2	3
CO3	3	2	2	2	3	2
CO4	2	2	2	1	2	2
CO5	3	2	3	-	3	2
Average	**2.4**	**1.6**	**2.5**	**1.5**	**2.4**	**2.25**

PPS203	DISTRIBUTED GENERATION AND MICRO GRID	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

To impart knowledge on the following topics

1. To familiarize with the concept of Distributed Generation
2. To expose the various distributed energy resources
3. To focus on the planning and protection of Distributed Generation
4. To study the concept of Micro Grid and to analyze the impact of MicroGrid
5. To understand the major issues on MicroGrid economics

UNIT - I INTRODUCTION TO DISTRIBUTED GENERATION 9

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

UNIT - II DISTRIBUTED ENERGY RESOURCES 9

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

UNIT - III DG PLANNING AND PROTECTION 9

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

UNIT - IV CONCEPT OF MICROGRID 9

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

UNIT - V IMPACTS OF MICROGRID 9

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

TOTAL: 45 PERIODS

COURSE OUTCOMES

At the end of this course, learners will be able to:

1. Understand the concepts of Distributed Generation and Microgrids.
2. Gain Knowledge about the various DG resources.
3. Familiarize with the planning and protection schemes of Distributed Generation.
4. Learn the concept of Microgrid and its mode of operation.
5. Acquire knowledge on the impacts of Microgrid.

REFERENCES

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

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

CO - PO MAPPING

PPS203	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	1	2	1	1	2	1
CO2	-	2	-	1	3	2
CO3	1	2	-	1	3	2
CO4	2	-	3	1	2	1
CO5	3	2	3	2	3	2
Average	**1.75**	**2.0**	**2.3**	**1.2**	**2.6**	**1.2**

PPS204	ENERGY STORAGE TECHNOLOGIES	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To gain basic knowledge on energy storage techniques
2. To impart knowledge on battery types
3. To understand the concept of energy storage technologies
4. To gain knowledge on fuel cell energy storage technology
5. To gain knowledge on designing and applications of Energy storage system.

UNIT - I INTRODUCTION 9

Necessity of energy storage- different types of energy storage- mechanical- chemical- electrical- electrochemical- biological- magnetic- electromagnetic- thermal- comparison of energy storage technologies.

UNIT - II BATTERIES 9

Lithium-Ion Batteries-Lead Batteries-Redox Flow Batteries-Vanadium Redox Flow batteries-Nickel-Cadmium Batteries-Electrochemical Capacitors-Iron Chromium flow batteries-Sodium Sulphur battery.

UNIT - III ENERGY STORAGE TECHNOLOGY 9

Thermal Energy storage- sensible and latent heat- phase change materials- Energy and exergy analysis of thermal energy storage- Electrical Energy storage-super-capacitors-Magnetic Energy Storage-Superconducting systems- Mechanical-Pumped hydro- flywheels and pressurized air energy storage- Chemical-Hydrogen production and storage.

UNIT - IV ENERGY STORAGE IN FUEL CELL 9

Fuel cells- Principle of direct energy conversion using fuel cell- thermodynamics of fuel cells- Types of fuel cells- AFC- PEMFC- MCFC- SOFC- Microbial fuel cell- Fuel cell performance- Electrochemical Energy Storage.

UNIT - V DESIGN AND APPLICATIONS OF ENERGY STORAGE 9

Renewable energy storage-Battery sizing and stand-alone applications- stationary (Power Grid application)- Small scale application-Portable storage systems and medical devices- Mobile storage Applications- Electric vehicles (EVs)- types of EVs- batteries and fuel cells- future technologies- hybrid systems for energy storage.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Ability to understand the principles energy storage techniques
2. Ability to study about the battery types
3. Ability to study about the energy storage technologies such as thermal, Mechanical and pumped hydro.
4. Ability to study about the fuel cell energy storage technology
5. Ability to know about the designing and applications of energy storage and impart knowledge on Electric vehicles.

REFERENCES

1. Huggins R. A.," Energy Storage: Fundamentals, Materials and Applications", Springer Publisher- Delhi 2016.
2. J. Jensen and B. Sorenson," Fundamentals of Energy Storage", Wiley-Interscience, New York 2007.
3. R. O'Hayre, S. Cha, W. Colella and F. B. Prinz," Fuel cell Fundamentals" ,Wiley Publications, 2014.
4. Battery Systems Engineering by C. D. Rahn and C. Wang, Wiley Publications, 2013.
5. F. P. Miller, A. F. Vandome, M. B. John, "Compressed air energy storage", VDM publishing, 2022.

CO - PO MAPPING

PPS204	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1		1	-	-	2	-
CO2	2	1	2	-	3	-
CO3	2	2	2	-	3	-
CO4	3	2	3	-	3	3
CO5	2	2	2	2	2	3
Average	**2.25**	**1.6**	**2.25**	**1.0**	**2.6**	**3.0**

PPS205	POWER QUALITY	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

To impart knowledge on the following topics

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

UNIT - I INTRODUCTION 9

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

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 loads – three phase balanced system – three phase unbalanced system – three phase unbalanced and distorted source supplying non-linear loads – concept of power factor – 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 – Static VAR Compensator (SVC)

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, IPFC

TOTAL: 45 PERIODS

COURSE OUTCOMES

At the end of this course, learners will be able to:

1. Comprehend the consequences of Power Quality issues
2. Conduct harmonic analysis of single phase and three phase systems supplying non-linear loads
3. Design passive filter for load compensation
4. Design active filters for load compensation
5. Understand the mitigation techniques using custom power devices such as distribution static compensator (DSTATCOM), dynamic voltage restorer (DVR) & UPQC.

REFERENCES

1. Arindam Ghosh and Gerad Ledwich "Power Quality Enhancement Using Custom Power Devices", Kluwer Academic Publishers, First Edition, 2002.
2. G.T.Heydt, "Electric Power Quality", Stars in a Circle Publications, Second Edition, 1994.
3. R.C.Duggan, "Electric Power Systems Quality", Tata MC Graw Hill Publishers, Third Edition, 2012.
4. Arrillga, "Power System Harmonics", John Wiely and Sons, 2003
5. Derek A.Paice, "Power Electronic Converter Harmonics" IEEE Press, 1995

CO - PO MAPPING

PPS205	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	-	3	3	3	2
CO2	3	-	3	3	3	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
Average	**3.0**	-	**3.0**	**3.0**	**3.0**	**2.0**

PROFESSIONAL ELECTIVE – III

PPS301	POWER SYSTEM RELIABILITY	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To introduce the objectives of Load forecasting.
2. To study the fundamentals of Generation system, Transmission system and Distribution.
3. To study the transmission system reliability analysis.
4. To illustrate the basic concepts of Expansion planning.
5. To impart knowledge on the fundamental concepts of the Distribution system planning.

UNIT - I INTRODUCTION 9

Definition of Reliability and Failure - Bathtub Curve - Concepts of Probability- Evaluation Techniques: Markov Process, Recursive Technique - Security levels of system – Reliability cost – Adequacy indices – Functions of system security – Contingency analysis – Linear sensitivity factors.

UNIT - II GENERATION CAPACITY 9

Generation system models –Capacity outage probability tables – Loss of load indices – Equivalent forced outage rate – Capacity expansion analysis – Scheduled outages – Evaluation methods on period basis.

UNIT - III TRANSMISSION SYSTEM 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 not served.

UNIT - IV PROBABILITY APPROACH FOR GENERATION 9

Introduction – Radial configurations – Conditional probability approach – Network configurations – State selection – System and load point indices – Application to practical system – Data requirements for composite system reliability evaluation.

UNIT - V DISTRIBUTION SYSTEM AND PROTECTION 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

1. Acquire design knowledge of system components in reliability point of view.
2. Understand the importance of customer oriented and system-oriented indices.
3. Familiarize with reliability evaluation methodologies.
4. Ability to understand the concepts of Expansion planning.
5. knowledge on the fundamental concepts of the Distribution system planning.

REFERENCES

1. Dr. K. Uma Rao, “Power system operation & control”, Wiley-India, First edition, 2013.
2. R.L. Sullivan, “Power System Planning”, Tata McGraw Hill Publishing Company Ltd,1977.
3. X.Wang & J.R. McDonald, “Modern Power System Planning”, McGraw Hill Book 38 Company, 1994.
4. T.Gonen, “Electrical Power Distribution Engineering”, McGraw Hill Book Company, 1986.
5. B.R. Gupta, “Generation of Electrical Energy”, S.Chand Publications 1983.
6. Roy Billinton, R.N. Allan, “Reliability Evaluation of Power Systems”, Springer,1996.

CO - PO and CO - PSO MAPPING

PPS301	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	2	1	2	-	3	2
CO2	1	1	2	1	2	2
CO3	3	2	2	-	2	3
CO4	3	2	3	-	3	2
CO5	3	2	3	1	3	2
Average	**2.4**	**1.6**	**2.4**	**0.4**	**2.6**	**2.2**

PPS302	EHVAC TRANSMISSION	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To introduce the concept of EHVAC Transmission lines
2. To understand the Electrostatic field of AC lines
3. To understand the Corona HV lines
4. To gain knowledge on Power control techniques
5. To gain knowledge on Transient limits

UNIT - I INTRODUCTION 9

EHVAC transmission line trends and preliminary aspect - standard transmission voltages Estimation at line and ground parameters-Bundle conductors: Properties - Inductance and Capacitance of EHV lines – Positive, negative and zero sequence impedance – Line Parameters for Modes of Propagation.

UNIT - II ELECTROSTATIC FIELDS 9

Electrostatic field and voltage gradients – Calculations of electrostatic field of AC lines – Effect of high electrostatic field on biological organisms and human beings – Surface voltage gradients and Maximum gradients of actual transmission lines – Voltage gradients on sub conductor.

UNIT - III POWER CONTROL 9

Electrostatic induction in un energized lines – Measurement of field and voltage gradients for three phase single and double circuit lines – Un energized lines. Power Frequency Voltage control and overvoltage in EHV lines: No load voltage – Charging currents at power frequency-Voltage control – Shunt and Series compensation – Static VAR compensation.

UNIT - IV CORONA EFFECTS AND RADIO INTERFERENCE 9

Corona in EHV lines – Corona loss formulae-Charge voltage diagram- Attenuation of traveling waves due to Corona – Audio noise due to Corona, its generation, characteristic and limits. Measurements of audio noise radio interference due to Corona - properties of radio noise – Frequency spectrum of RI fields –Measurements of RI and RIV. Reduction of corona.

UNIT - V STEADY STATE AND TRANSIENT LIMITS 9

Design of EHV lines based on steady state and transient limits - EHV cabilitys and their characteristics-Introduction six phase transmission – Ultra high voltage AC/ DC power transmission.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Ability to understand the principles and types of EHVAC system
2. Ability to analyze the electrostatic field of AC lines
3. Ability to study about the compensation
4. Ability to study about the corona in E.H.V. lines
5. Ability to analyze the steady state and transient limits

REFERENCES

1. Rokosh Das Begamudre,” Extra High Voltage AC Transmission Engineering”–Wiley Eastern Ltd., New Delhi 1990.
2. S. Rao, “HVAC and HVDC Transmission, Engineering and Practice” Khanna Publisher, New Delhi, 1990.
3. Subir Ray, “An Introduction to High Voltage Engineering”, Prentice Hall of India Private Limited, 2013.
4. RD Begamudre, “Extra High Voltage AC Transmission Engineering”, New Academic Science Ltd., 4th Edition 2011.

CO - PO MAPPING

PPS302	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	3	3	3	-	3
CO2	3	3	3	3	3	-
CO3	3	3	3	3	3	3
CO4	3	3	3	3	-	3
CO5	3	3	3	3	3	3
Average	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**

PCU101 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY

L	T	P	C
3	0	0	3

OBJECTIVES:

The students will be able

1. To gain a broad conceptual understanding of the various aspects of electromagnetic (EM) interference and compatibility.
2. To understand the ways of mitigating EMI by using shielding, grounding and filtering.
3. To realize the concepts of PCB tracing, termination and implementation.
4. To understand how EMI impacts wireless and broadband technologies.
5. To understand different standards being followed across the world in the fields of EMI/EMC.

UNIT - I EMI NOISE SOURCES, EMI ANALYSIS 9

Definition of EMI and EMC, Sources and Simulators, Propagation Methods, Electromagnetic environment, Frequency spectrum conservations, Electrical Noise Sources, Common-Mode and Differential-Mode Currents

UNIT - II INTERFERENCE CONTROL TECHNIQUES 9

Equipment screening, Cable screening, Grounding, Shielding effectiveness, Power-line filters, Isolation, Balancing, Signal-line filters, Nonlinear protective devices.

UNIT - III PCB TRACE ROUTING AND TERMINATIONS 9

Typical PCB Trace Topologies, Trace Routing Design Guidelines, Routing Differential Pair Signals, Layer Jumping – Use of Vias, Routing over a Split Plane, Fundamental Concepts of Trace Termination, Termination Methodologies and Implementation.

UNIT - IV EMC CONSIDERATIONS IN WIRELESS AND BROADBAND TECHNOLOGIES 9

Efficient use of frequency spectrum - EMC, interoperability and coexistence - Specifications and alliances - Transmission of high-frequency signals over telephone and power networks – EMC and digital subscriber lines - EMC and power line telecommunications.

UNIT - V EMC STANDARDS AND MEASUREMENTS 9

Need for standards - The international framework - Human exposure limits to EM fields -EMC measurement techniques - Measurement tools - Test environments.

TOTAL: 45 Periods

COURSE OUTCOMES:

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

1. Understand and Gain basic knowledge of problems associated with EMI and EMC from electronic circuits and systems.
2. Analyze the functions of a ground, understanding about cables and connectors.
3. Understand the concepts of PCB tracing, termination and implementation
4. Discuss the impact of EMC on wireless and broadband technologies
5. Able to apply the knowledge gained in selecting proper gadgets/devices/ application/ Systems as per EMC norms specified by regulating authorities.

REFERENCES

1. Clayton R Paul, "Introduction to Electromagnetic Compatibility", John Wiley and Sons, Second Edition, 2010.
2. H. W. Ott, "Electromagnetic Compatibility Engineering", 2nd Edition, John Wiley & Sons, 2011.
3. Kodali V P, "Engineering Electromagnetic Compatibility", Wiley India, Second Edition, 2010.
4. Ralph Morrison, "Grounding and Shielding: Circuits and Interference", John Wiley & Sons, 6th Edition, 2016.

5. Christopoulos C, Principles and Techniques of Electromagnetic Compatibility, CRC Press, Second Edition, Indian Edition, 2013.
6 Electromagnetic Interference and Compatibility", IMPACT series, IIT-Delhi, Modules1-9.

CO - PO MAPPING

PCU101	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	2	2	1	1	1
CO2	3	2	2	2	-	1
CO3	3	3	2	2	-	1
CO4	3	3	2	3	2	2
CO5	3	3	3	3	2	1
Average	**3.0**	**2.6**	**2.2**	**2.2**	**1.6**	**1.2**

PPS303	INDUSTRIAL POWER SYSTEM ANALYSIS AND DESIGN	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To impart knowledge on Motor Starting Studies.
2. To understand the need for power factor correction and analyse the various methods that are used in the Power Factor Correction studies.
3. To learn about the sources of harmonics, evaluate the harmonics present in the power system and mitigate them by filters.
4. To analyse the sources that can cause the voltage flicker and find solutions to minimize the flicker.
5. 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-Harmonic analysis for 33kV distribution network 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

1. Perform motor starting studies.
2. To model and carry out power factor correction studies.
3. Perform harmonic analysis and reduce the harmonics by using filters.
4. Carry out the flicker analysis by proper modeling of the load and its minimization.
5. Design the appropriate ground grid for electrical safety.

REFERENCES

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3. Ramasamy Natarajan, "Computer-Aided Power System Analysis", Marcel Dekker Inc., 2002.
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CO - PO MAPPING

PPS303	PROGRAM OUTCOMES					
	1	2	3	4	5	6
CO1	1	-	-	1	-	-
CO2	1	2	1	1	1	-
CO3	1	2	-	1	-	-
CO4	1	2	2	1	2	1
CO5	1	-	3	1	2	2
Average	**1.0**	**2.0**	**2.0**	**1.0**	**1.66**	**1.5**

PPS304	ADVANCED POWER SYSTEM DYNAMICS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. 1.To perform transient stability analysis using unified algorithm..
2. To perform dynamic analysis using unified algorithm.
3. To impart knowledge on sub-synchronous resonance and oscillations.
4. To analyze voltage stability problem in power system.
5. To familiarize the methods of transient stability enhancement.

UNIT - I TRANSIENT STABILITY ANALYSIS 9

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 transient stability.

UNIT - II UNIFIED ALGORITHM FOR DYNAMIC ANALYSIS OF POWER SYSTEMS 9

Need for unified algorithm - numerical integration algorithmic steps - truncation error - variable step size – handling the discontinuities - numerical stability - application of the algorithm for transient. Mid-term and long-term stability simulations.

UNIT - III SUBSYSNCHRONOUS RESONANCE (SSR) AND OSCILLATIONS 9

Subsynchronous Resonance (SSR) – Types of SSR - Characteristics of series- Compensated transmission systems – Modeling 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 subsynchronous oscillations – time-domain simulation of subsynchronous 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 STATCOM.

UNIT - IV TRANSMISSION, GENERATION AND LOAD 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 – Load Aspects – Voltage dependence of loads – Load restoration dynamics –Induction motors – Load tap changers – Thermostatic load recovery – General aggregate load models.

UNIT - V ENHANCEMENT OF TRANSIENT STABILITY AND COUNTER MEASURES FOR SUB SYNCHRONOUS RESONANCE 9

Principle behind transient stability enhancement methods: high-speed fault clearing, reduction of transmission system reactance, regulated shunt compensation, dynamic braking, reactor switching, independent pole-operation of circuit-breakers, single-pole switching, fast-valving, high-speed excitation systems; NGH damper scheme, Using FACTS controllers.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Learners will be able to understand the concepts of transient stability analysis using unified algorithm.
2. Analyze the effect of dynamic analysis using unified algorithm.
3. Analyze and enhance sub-synchronous resonance and oscillations.
4. Analyze voltage stability problem in power system.
5. Study and analyze the methods of transient stability enhancement.

REFERENCES

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/August,1972.

5. Roderick J.Frowd and J. C. Giri, “Transient stability and Long term dynamics unified”, IEEE Trans., Vol 101, No. 10, October1982.

6. M.Stubbe, A.Bihain,J.Deuse, J.C.Baader, “A New Unified software program for the study of the dynamic behaviour of electrical power system,” IEEE Transaction, Power Systems, Vol.4.No.1,Feb:1989,pp.129-138.

CO - PO MAPPING

PPS304	**PROGRAM OUTCOMES**					
	1	**2**	**3**	**4**	**5**	**6**
CO1	1	3	3	-	-	-
CO2	2	2	2	-	-	-
CO3	3	1	3	-	-	-
CO4	1	3	2	-	-	-
CO5	3	1	2	-	-	-
Average	**2.0**	**2.0**	**2.4**	-	-	-

PROFESSIONAL ELECTIVE - IV & V

PPS401	COMPUTER RELAYING AND WIDE AREA MEASUREMENT SYSTEMS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To discriminate conventional relays and computer relays.
2. To comprehend the operating values of a computer relays.
3. To provide exposure to wide area measurement systems through the computer hierarchy in the substation, system relaying and control.
4. To inculcate knowledge on phasor measurement unit and its application to power system.
5. To enhance the conventional power system studies with wide area measurement techniques.

UNIT - I INTRODUCTION 9

Historical background - Expected benefits - Computer relay architecture - Analog to digital converters - Anti-aliasing filters - Substation computer hierarchy - Fourier series Exponential fourier series - Sine and cosine fourier series – Phasor.

UNIT - II FILTERS IN COMPUTER RELAYING 9

Walsh functions - Fourier transforms - Discrete fourier transform - Random processes - Filtering of random processes - Kalman filtering - Digital filters - Windows and windowing - Linear phase Approximation - Filter synthesis – Wavelets - Elements of artificial intelligence – Application of Kalman filtering.

UNIT - III COMPUTATION OF PHASORS 9

Introduction - Phasor representation of sinusoids - Fourier series and Fourier transform and DFT Phasor representation - Phasor Estimation of Nominal Frequency Signals - Formulas for updating phasors – Non-recursive updates - Recursive updates - Frequency Estimation.

UNIT - IV PHASOR MEASUREMENT UNITS 9

A generic PMU - The global positioning system - Hierarchy for phasor measurement systems - Functional requirements of PMUs and PDCs - Transient Response of: Phasor Measurement Units, of instrument transformers, filters. Transient response during electromagnetic transients and power swings.

UNIT - V PHASOR MEASUREMENT APPLICATIONS 9

State Estimation - History, Operator's load flow - Weighted least square: least square, Linear weighted least squares, Nonlinear weighted least squares - Static state estimation - State estimation with Phasors measurements - Linear state estimation – Protection system with phasor inputs: Differential and distance protection of transmission lines - Adaptive protection - Adaptive out-of-step protection.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Ability to demonstrate knowledge of fundamental theories, principles and practice of computer relaying, wide area measurement system.
2. Ability to analyze the power system with computer relaying and wide area measurement system.
3. Ability to validate the recent relaying technologies which work towards smart grid.
4. Ability to design wide area measurement systems for Smart grid.
5. Ability to compare the performance of modern relaying schemes and measurement techniques with the conventional one.

REFERENCES

1. Stanley H. Horowitz, Arun G. Phadke ,"Power System Relaying", Fourth edition, John Wiley and Sons Ltd,2014.
2. Arun G. Phadke, James S. Thorp, "Computer Relaying for Power Systems", Second edition, John Wiley and Sons Ltd.,2009.
3. Antonello Monti, Carlo Muscas , Ferdinanda Ponci , "Phasor Measurement Units and Wide Area Monitoring Systems ", 2016.
4. A.G. Phadke , J.S. Thorp, "Synchronized Phasor Measurements and Their Applications", 2010.

CO - PO MAPPING

PPS401	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	2	1	1	1	2	-
CO2	2	1	1	1	2	-
CO3	2	1	1	1	2	-
CO4	2	1	1	1	2	-
CO5	2	1	1	1	2	-
Average	**2.0**	**1.0**	**1.0**	**1.0**	**2.0**	**-**

PPS402	APPLICATION OF DSP TO POWER SYSTEM PROTECTION	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

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

UNIT - I DIGITAL SIGNAL PROCESSING TECHNIQUES 9

Sampling-Principle of scaling-aliasing-Decimation, Interpolation - Fourier analysis based algorithms - 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 systems -Conversion subsystem -digital relay subsystem Numerical relay for generator, transformer, feeder, busbar protection.

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.-short window Wavelet based fault identification techniques-sliding window-FWHT-signal analysis and synthesis-AC/DC cable fault location-intrinsic and extrinsic fault-harmonic filtering in fault analysis.

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

1. Ability to apply DSP techniques for digital protection
2. Ability to capable of decision making algorithm suitable for digital relaying applications.
3. Ability to employ FIR based algorithms for digital relaying.
4. Ability to do transformer protection using digital techniques.
5. Ability to perform coordinated operation of relays for specific purposes.

REFERENCES

1. Waldemar Rebizant, Janusz Szafran, Andrzej Wiszniewski , “Digital Signal Processing in Power System Protection and Control”, Springer-Verlag London Limited, 2011.
2. J.G. Proakis and D.G. Manolakis, “Digital Signal Processing Principles, Algorithms”, Prentice Hall International, 1996.
3. Y.G. Paithankar and S.R Bhide, “Fundamentals of Power System Protection”, PHI Learning, 2nd edition, 2013.

4. A.G. Phadke and J.S. Thorp, Computer Relaying for Power Systems, John Wiley & Sons, New York, 1988.

5 J.L. Blackburn, Protective Relaying: Principles and Applications, Marcel Dekker, New York, 1987.

CO - PO MAPPING

PPS402	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	1	2	1	-	1	-
CO2	1	1	2	-	3	1
CO3	2	-	3	1	1	1
CO4	1	2	1	2	-	1
CO5	2	2	2	-	3	1
Average	**1.4**	**1.75**	**1.8**	**1.5**	**2.33**	**1.0**

PPS403 POWER SYSTEM INSTRUMENTATION **L T P C**

3 0 0 3

COURSE OBJECTIVES:

1. To use the processors in the process and their relative merits to be brought out.
2. To explain the algorithms used in the investigation procedure and error analysis.
3. To offer an opportunity to innovate newer procedures and better methods for effective design of instrumentation systems for power networks.
4. To provide the knowledge on various controls and measurements involved in power plant.
5. To import knowledge on distribution automation and substation controls.

UNIT - I MEASUREMENTS AND SCADA SYSTEMS 9

Measurement and error analysis. Object and philosophy of power system instrumentation to measure large currents, high voltages, Torque and Speed - Standard specifications - Data acquisition systems for Power System applications - Data Transmission and Telemetry – Block Diagram of PLC- PLC equipment - computer control of power system - Man Machine Interface.

UNIT - II POWER PLANT INSTRUMENTATION 9

Piping and Instrumentation diagram of thermal and nuclear power plants - Fuel measurement – gas analysis meters - smoke measurement – Dust Measurement Monitoring systems – measurement and control of furnace draft – measurement and control of combustion – Turbine monitoring and control: speed, vibration, shell temperature monitoring – radiation detection instruments – process sensors for nuclear power plants – spectrum analyzers – nuclear reactor control systems and allied instrumentation.

UNIT - III DISTRIBUTION AUTOMATION 9

Definitions – automation switching control – management information systems (MIS) – remote terminal units – communication method for data transfer – consumer information service (CIS) – graphical information systems (GIS) - automatic meter reading (AMR) – Remote control load management.

UNIT - IV SUBSTATION INSTRUMENTATION 9

Sub-station automation – requirements – control aspects in substations – feeder automation – consumer side automation – reliability - GPIB programmable test instruments - microprocessor / microcontroller based GPIB controllers

UNIT - V ENERGY MANAGEMENT TECHNIQUES AND INSTRUMENTS 9

Demand side management (DSM)– DSM planning – DSM Techniques – Load management as a DSM strategy – energy conservation – tariff options for DSM - Energy audit – instruments for energy audit – Energy audit for generation, distribution and utilization systems – economic analysis.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Understand the basics of instrumentation and SCADA system implementation in PS.
2. Analyze and implement the controls involved in power plant instrumentation.
3. Understand the functioning of distribution automation in power system network.
4. Analyze concepts of substation automation and to implement the controls.
5. Understand the energy management techniques and energy audit.

REFERENCES

1. Murphy. W.R and McKay G “Energy Management” Butterworths Publications, London 1982.
2. Pabla. A.S “Electric power distribution “, Tata McGraw Hill; New Delhi 2004.
3. MahalanaBis A K, Kothari D P and Ahson S I “ Computer aided Power System analysis and control” - Tata McGraw Hill; New Delhi 1988.
4. Liptak B.G,” Instrumentation in Process Industries”, Vol I and II, Chilton Book Co., 1973.
5. Sherry A., Modern Power Station Practice, Vol.6 (Instrumentation, controls and Testing), Pergamon Press,1971.
6. Wayne C Tuner “Energy Management Hand Book” John Wiley and Sons, 1982.

CO - PO MAPPING

PPS403	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	2	1	1	-	1	2
CO2	3	2	2	-	2	2
CO3	2	2	1	-	2	2
CO4	3	2	1	-	2	2
CO5	2	2	1	2	2	2
Average	**2.4**	**1.8**	**1.2**	**2.0**	**1.8**	**2.0**

PPS501 **HIGH VOLTAGE TECHNOLOGY** **L T P C**

3 0 0 3

COURSE OBJECTIVES

1. To provide strong knowledge on different types of electrical stresses on power system and equipment.

2. To impart knowledge on generation of high AC and DC voltages.

3. To provide adequate knowledge to simulate and generate impulse voltages and impulse currents.

4. To study expose the different techniques of measuring High voltages and high currents.

5. To provide awareness on electro-static hazards and safety measures.

UNIT - I DIRECT VOLTAGE GENERATION **9**

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

UNIT - II ALTERNATE VOLTAGE GENERATION **9**

Testing transformer – single unit testing transformer, cascaded transformer –equivalent circuit of cascaded transformer –resonant circuits – resonant transformer – voltage regulation.

UNIT - III IMPULSE VOLTAGES AND CURRENT **9**

Impulse voltage, general shape and definition of lightning impulses, generator circuit –controlled switching – multistage impulse generator circuits – Switching impulse generator circuits – Generation of impulse currents, generation of non-standard impulse voltages and very fast transient voltage (VFTO)- Relevant IS and IEC Standards.

UNIT - IV HIGH VOLTAGE MEASUREMENTS 9

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

UNIT - V SAFETY MEASURES AND ELECTROSTATIC HAZARDS 9

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

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Acquire Ability to design, simulate and generate HVDC.

2. Familiarize with Ability to design, simulate and generate HVAC.

3. Ability to design, simulate and generate impulse voltage and current.

4. knowledge on the Ability to design and analyze the suitable measuring circuits for HV.

5. Ability to provide safety measures against electrostatic hazards.

REFERENCES

1. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsevier India Pvt. Ltd., Second Edition, 2008

2. Naidu M S and Kamaraju V, “High Voltage Engineering”, Tata Mc Graw-hill Publishing Company Ltd., Fifth Edition., New Delhi, 2017.

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4. Adolf J. Schwab, “High Voltage Measurement Techniques”, M.I.T Press,1972.

5. Indian Electricity Rules; IS-5216; Electrical Safety Handbook by John Cadick.

CO - PO and CO - PSO MAPPING

PPS501	**PROGRAM OUTCOMES**					
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	1	2	2	1	1
CO2	3	1	2	2	1	1
CO3	3	1	2	2	1	1
CO4	3	1	2	2	1	1
CO5	3	1	2	2	1	1
Average	**3.0**	**1.0**	**2.0**	**2.0**	**1.0**	1.0

PPS502	ELECTRIC VEHICLES AND POWER MANAGEMENT	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To understand the concept of electric vehicles and its operations.
2. To provide knowledge about Power train components.
3. To understand the power electronics and motor drives.
4. To understand the need for energy storage in hybrid vehicles.
5. To provide knowledge about alternative energy storage technologies that can be used in electric vehicles.

UNIT - I ELECTRIC VEHICLES AND VEHICLE MECHANICS 9

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

UNIT - II ARCHITECTURE OF EV's AND POWER TRAIN COMPONENTS 9

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

UNIT - III POWER ELECTRONICS AND MOTOR DRIVES 9

Electric drive components – Power electronic switches- four quadrant operation of DC drives- Inverter based V/f Operation (motoring and braking) of induction motor drive system - Induction motor and permanent magnet synchronous motor-based vector control operation – Switched reluctance motor (SRM) drives- EV motor sizing.

UNIT - IV BATTERY ENERGY STORAGE SYSTEM 9

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

UNIT - V ALTERNATIVE ENERGY STORAGE SYSTEMS 9

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

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Understand the concept of electric vehicle and energy storage systems.
2. Describe the working and components of Electric Vehicle and Hybrid Electric Vehicle.
3. Know the principles of power converters and electrical drives.
4. Illustrate the operation of storage systems such as battery and super capacitors.
5. Analyze the various energy storage systems based on fuel cells and hydrogen storage.

REFERENCES

1. Iqbal Hussain, “Electric and Hybrid Vehicles: Design Fundamentals”, Second Edition” CRC Press, Taylor & Francis Group, Second Edition, 2011.
2. Ali Emadi, Mehrdad Ehsani, John M.Miller, “Vehicular Electric Power Systems”, Special Indian Edition, Marcel dekker, Inc., 2010.
3. Mehrdad Ehsani, YiminGao, Sebastian E. Gay, Ali Emadi, “Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design”, CRC Press, 2004.
4. C.C. Chan and K.T. Chau, “Modern Electric Vehicle Technology”, Oxford University Press, 2001.
5. Wie Liu, “Hybrid Electric Vehicle System Modeling and Control”, Second Edition, John Wiley & Sons, 2017.

CO - PO MAPPING

PPS502	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	1	2	1	-	3
CO2	3	1	2	1	-	3
CO3	3	1	2	1	-	3
CO4	3	1	2	1	-	3
CO5	3	1	2	1	-	3
Average	**3.0**	**1.0**	**2.0**	**1.0**	**-**	**3.0**

PPS503	ENERGY MANAGEMENT AND AUDITING	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To acquaint and equip the students in energy auditing in industries and house hold sectors for increasing energy efficiency.
2. To impart knowledge on energy management and facilitate application of energy conservation techniques in process industries.
3. To impart knowledge on thermal and electrical utilities for evaluating energy saving potential.
4. To familiarize on the trends in economics of energy use in various sectors and facilitate energy modeling to make policy decisions.
5. To identify sources of energy loss and target savings.

UNIT - I ENERGY SCENARIO 9

Basics of Energy and its various forms - Conventional and non-conventional sources - Energy policy - Energy conservation act 2001, Amendments (India) in 2010 - Need for energy management- Designing and starting an energy management program - Energy managers and energy auditors - Roles and responsibilities of energy managers - Energy labelling and energy standards- strategy for the future

UNIT - II ENERGY COST AND LOAD MANAGEMENT 9

Important concepts in an economic analysis - Economic models-Time value of money-Utility rate structures- Cost of electricity-Loss evaluation- Load management: Demand control techniques-Utility monitoring and control system-HVAC and energy management-Economic justification- cost index – financial management – financing options.

UNIT - III ENERGY MANAGEMENT 9

Demand side management (DSM)– DSM planning – DSM techniques – Load management as a DSM strategy – Energy conservation – Tariff options for DSM.

UNIT - IV ENERGY AUDITING 9

Definition – Energy audit methodology: audit preparation, execution and reporting – Financial analysis– Sensitivity analysis – Project financing options -

Instruments for energy audit – Energy audit for generation, distribution and utilization systems – Economic analysis.

UNIT - V ENERGY EFFICIENT TECHNOLOGIES 9

Energy saving opportunities in electric motors - Power factor improvement benefit and techniques- Shunt capacitor, Synchronous Condenser and Phase Advancer -

Energy conservation in industrial drives, electric furnaces, ovens and boilers - Lighting techniques: Natural, CFL, LED lighting sources and fittings.

TOTAL: 45 PERIODS

COURSE OUTCOMES

1. Understand the present energy scenario and role of energy managers.
2. Comprehend the Economic Models for cost and load management.
3. Configure the Demand side energy management through its control techniques, strategy and planning.
4. Understand the process of energy auditing.
5. Implement energy conservation aspects in industries

REFERENCES

1. Abbi, Y.P. and Jain, S., Handbook on Energy Audit and Environment Management, Teri Bookstore (2006).
2. Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, Guide to Energy Management, Fifth Edition, The Fairmont Press, Inc., 2006
3. Eastop T. D & Croft D. R, Energy Efficiency for Engineers and Technologists, Logman Scientific & Technical, ISBN-0-582-03184, 1990.
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6. IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities,IEEE, 1996.
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8. https://www.eeeguide.com/power-factor-improvement.
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10. S.C. Bhatia and Sarvesh Devraj, “Energy Conservation”, Woodhead Publishing India Pvt. Ltd., 2016.

CO - PO MAPPING

PPS503	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	2	2	2	1	2	-
CO2	2	3	2	1	2	1
CO3	2	2	2	1	2	2
CO4	2	2	2	1	2	-
CO5	2	3	2	1	2	3
Average	**2.0**	**2.4**	**2.0**	**1.0**	**2.0**	**2.0**

PPS504 **SMART GRID** **L T P C**

3 0 0 3

COURSE OBJECTIVES:

To impart knowledge on the following topics

1. To Study about Smart Grid and its present developments.
2. To familiarize about Smart Grid technologies.
3. To familiarize the different smart meters and advanced metering infrastructure.
4. To illustrate the basic concepts of the power quality management issues in Smart Grid.
5. To impart knowledge on the fundamental concepts of the high performance computing for Smart Grid applications.

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, Concept of Resilient & Self Healing Grid, Present development & International policies in Smart Grid, Diverse Prospective from experts and global Smart Grid initiatives.

UNIT - II SMART GRID TECHNOLOGIES 9

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

UNIT - III SMART METERS AND ADVANCED METERING INFRASTRUCTURE 9

Introduction to Smart Meters, Advanced Metering infrastructure (AMI) drivers and benefits, AMI protocols, Standards and initiatives, AMI needs in the smart grid, Phasor Measurement Unit(PMU), Intelligent Electronic Devices (IED) & their application for monitoring & protection.

UNIT - IV POWER QUALITY MANAGEMENT IN SMART GRID 9

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

UNIT - V HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATIONS 9

Networking Fundamentals - Local Area Network (LAN), House Area Network (HAN), Wide Area Network (WAN), Broadband over Power line (BPL), IP based Protocols, Basics of Web Service and CLOUD computing to make Smart Grids smarter, Cyber Security for Smart Grid.

TOTAL: 45 PERIODS

COURSE OUTCOMES

At the end of this course, learners will be able to:

1. Learners will develop more understanding on the concepts of Smart Grid and its present developments.
2. Learners will study about different Smart Grid technologies.
3. Learners will acquire knowledge about different smart meters and advanced metering infrastructure.
4. Learners will have knowledge on power quality management in Smart Grids
5. Learners will develop more understanding on LAN, WAN and Cloud Computing for Smart Grid applications.

REFERENCES

1. Stuart Borlase "Smart Grid: Infrastructure, Technology and Solutions", CRC Press 2012.
2. Janaka Ekanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama,"Smart Grid: Technology and Applications", Wiley 2012.
3. Vehbi C. Gungor, DilanSahin, TaskinKocak, Salih Ergüt, Concettina Buccella, Carlo Cecati, and Gerhard P. Hancke, "Smart Grid Technologies: Communication Technologies and Standards" IEEE Transactions On Industrial Informatics, Vol. 7, No. 4, November 2011.
4. Xi Fang, Satyajayant Misra, Guoliang Xue, and Dejun Yang "Smart Grid – The New and Improved Power Grid: A Survey", IEEE Transaction on Smart Grids, vol. 14, 2012.

CO - PO MAPPING

PPS504	PROGRAM OUTCOMES					
	1	**2**	**3**	**4**	**5**	**6**
CO1	1	-	-	1	-	-
CO2	1	2	-	1	1	1
CO3	1	2	-	1	2	-
CO4	1	-	-	1	1	2
CO5	1	2	2	1	-	2
Average	**1.0**	**2.0**	**2.0**	**1.0**	**1.33**	**1.67**

PPS505 RENEWABLE ENERGY SYSTEMS L T P C

3 0 0 3

COURSE OBJECTIVES:

To impart knowledge on the following topics

1. Awareness about renewable Energy Sources and technologies.
2. Adequate inputs on a variety of issues in harnessing renewable Energy.
3. Recognize current and possible future role of renewable energy sources.
4. To get adequate knowledge of PV systems and Wind Energy systems.
5. To understand the biomass energy system and other energy sources.

UNIT - I RENEWABLE ENERGY (RE) SOURCES 9

Environmental consequences of fossil fuel use, Importance of renewable sources of energy, Sustainable Design and development, Types of RE sources, Limitations of RE sources, Present Indian and international energy scenario of conventional and RE sources.

UNIT - II WIND ENERGY 9

Power in the Wind – Types of Wind Power Plants (WPPs)–Components of WPPs Working of WPPs- Siting of WPPs-Grid integration issues of WPPs.

UNIT - III SOLAR PV AND THERMAL SYSTEMS 9

Solar Radiation, Radiation Measurement, Solar Thermal Power Plant, Central Receiver Power Plants, Solar Ponds.- Thermal Energy storage system with PCM- Solar Photovoltaic systems : Basic Principle of SPV conversion – Types of PV Systems- Types of Solar Cells, Photovoltaic cell concepts: Cell, module, array ,PV Module I-V Characteristics, Efficiency & Quality of the Cell, series and parallel connections, maximum power point tracking, Applications of Solar PV in Electric Vehicle.

UNIT - IV BIOMASS ENERGY 9

Battery Basics- Introduction-Biomass resources –Energy from Biomass: conversion processes-Biomass Cogeneration-Environmental Benefits. Geothermal Energy: Basics, Direct Use, Geothermal Electricity. Mini/micro hydro power: Classification of hydropower schemes, Classification of water turbine, Turbine theory, Essential components of hydroelectric system.

UNIT - V OTHER ENERGY SOURCES 9

Tidal Energy: Energy from the tides, Barrage and Non-Barrage Tidal power systems. Wave Energy: Energy from waves, wave power devices. Ocean Thermal Energy Conversion (OTEC)- Hydrogen Production and Storage- Fuel cell: Principle of working- various types - construction and applications. Energy Storage System- Hybrid Energy Systems, Need for Hybrid Systems-Range and type of systems.

TOTAL: 45 PERIODS

COURSE OUTCOMES

At the end of this course, learners will be able to:

1. Ability to create awareness about renewable Energy Sources and technologies.
2. Ability to get adequate inputs on a variety of issues in harnessing renewable Energy.
3. Ability to recognize current and possible future role of renewable energy sources.
4. Ability to explain the various renewable energy resources and technologies and their applications.
5. Ability to understand basics about biomass energy.

REFERENCES

1. Joshua Earnest, Tore Wizeliu, Wind Power Plants and Project Development, PHI Learning Pvt. Ltd., New Delhi, 2011.
2. D.P.Kothari, K.C Singal, Rakesh Ranjan “Renewable Energy Sources and Emerging Technologies”, PHI Learning Pvt. Ltd., New Delhi,2013.
3. Scott Grinnell, “Renewable Energy & Sustainable Design”, CENGAGE Learning, USA, 2016.
4. A.K.Mukerjee and Nivedita Thakur,” Photovoltaic Systems: Analysis and Design”, PHI Learning Private Limited, New Delhi, 2011.

5. Richard A. Dunlap," Sustainable Energy" Cengage Learning India Private Limited, Delhi,2015.
6. Chetan Singh Solanki, "Solar Photovoltaics: Fundamentals, Technologies and Applications", PHI Learning Private Limited, New Delhi,2011.
7. Bradley A. Striebig, Adebayo A.Ogundipe and Maria Papadakis,"Engineering Applications in Sustainable Design and Development", Cengage Learning India Private Limited, Delhi, 2016.
8. Godfrey Boyle, "Renewable energy", Open University, Oxford University Press in association with the Open University, 2004.
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CO - PO MAPPING

PPS505	**PROGRAM OUTCOMES**					
	1	**2**	**3**	**4**	**5**	**6**
CO1	3	1	-	-	2	-
CO2	3	1	3	-	2	3
CO3	3	2	3	2	3	2
CO4	2	2	3	1	2	2
CO5	3	2	3	-	3	2
Average	**2.8**	**1.6**	**3.0**	**1.5**	**2.4**	**2.25**