ANNA UNIVERSITY, CHENNAI

UNIVERSITY DEPARTMENTS

REGULATIONS – 2015

CHOICE BASED CREDIT SYSTEM

M.E. POWER SYSTEMS ENGINEERING

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs) :

I. To prepare the students to have career in the electrical power industry/research organization/teaching.

II. To provide good foundation in mathematics and computational technology to analyze and solve problems encountered in electrical power industry.

III. Pursue lifelong learning and continuous improvement of their knowledge in the electrical power industry.

IV. To understand the national and global issues related to the electrical power industry and to be considerate of the impact of these issues on the environment and within different cultures.

V. Apply the highest professional and ethical standards to their activities in the electrical power industry.

VI. To equip the students in the state of art in the technologies in power generation, control and management as well as with alternate and new energy resources.

PROGRAMME OUTCOMES (POs):

On successful completion of the Programme,

a. To disseminate knowledge of the principles and practices of the electrical power industry regarding generation, transmission, distribution and electrical machines and their controls.

b. Be able to apply their knowledge of electrical power principles, as well as mathematics and scientific principles, to new applications in electrical power.

c. Be able to perform, analyze, and apply the results of experiments to electrical power application improvements.

d. Be able to look at all options in design and development projects and creativity and choose the most appropriate option for the current project.

e. Have the ability to function effectively as a member of a project team.

f. Be able to identify problems in electrical power systems, analyze the problems, and solve them using all of the required and available resources.

g. Be able to effectively communicate technical project information in writing or in personal presentation and conversation.

h. Be engaged in continuously learning the new practices,principles,and techniques of the electrical power industry.

i. Ability to work on application software packages for power system analysis and design.

j. Ability to develop indigenous software packages for power system planning and operational problems of utilities.

Program Educational Objective	Program Outcome									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
I	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	✓	✓	✓	✓	✓			✓	✓	✓
III								✓		
IV	✓		✓	✓		✓			✓	✓
V					✓		✓	✓	✓	✓
VI	✓	✓	✓	✓		✓		✓	✓	✓

			PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
YEAR 1	**SEM 1**	Advanced Power System Analysis	✓	✓	✓							
		Power System Operation and Control	✓	✓	✓							
		Power System Dynamics		✓			✓	✓		✓	✓	✓
		Analysis of Electrical Machines	✓		✓	✓						
		Applied Mathematics for Electrical Engineers		✓								
		Elective I										
		Power System Simulation Laboratory					✓			✓	✓	✓
	SEM 2	Analysis and Computation of Electromagnetic Transients in Power Systems	✓		✓	✓						
		Advanced Power System Protection						✓		✓	✓	✓
		Flexible AC Transmission Systems						✓		✓	✓	✓
		Restructured Power System							✓		✓	✓
		Elective II										
		Elective III										
		Advanced Power System Simulation Laboratory					✓	✓		✓	✓	✓

Attested

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		Technical Seminar							✓	✓	✓	✓
YEAR 2	**SEM 3**	Advanced Power System Dynamics						✓		✓	✓	✓
		Elective IV										
		Elective V										
		Project Work Phase I							✓		✓	✓
	SEM 4	Project Work Phase II							✓		✓	✓

Attested

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ANNA UNIVERSITY, CHENNAI
UNIVERSITY DEPARTMENTS
REGULATIONS – 2015
CHOICE BASED CREDIT SYSTEM
M.E. POWER SYSTEMS ENGINEERING
CURRICULA AND SYLLABI I TO IV SEMESTERS

SEMESTER - I

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	MA7156	Applied Mathematics for Electrical Engineers	FC	4	4	0	0	4
2.	PE7152	Analysis of Electrical Machines	PC	3	3	0	0	3
3.	PS7101	Power System Operation and Control	PC	3	3	0	0	3
4.	PS7151	Advanced Power System Analysis	PC	4	4	0	0	4
5.	PS7152	Power System Dynamics	PC	3	3	0	0	3
6.		Elective I	PE	3	3	0	0	3
PRACTICALS								
7.	PS7111	Power System Simulation Laboratory	PC	4	0	0	4	2
			TOTAL	**24**	**20**	**0**	**4**	**22**

SEMESTER - II

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	PS7251	Advanced Power System Protection	PC	3	3	0	0	3
2.	PS7252	Analysis and Computation of Electromagnetic Transients in Power Systems	PC	3	3	0	0	3
3.	PS7253	Flexible AC Transmission Systems	PC	3	3	0	0	3
4.	PS7254	Restructured Power System	PC	3	3	0	0	3
5.		Elective II	PE	3	3	0	0	3
6.		Elective III	PE	3	3	0	0	3
PRACTICALS								
7.	PS7211	Advanced Power System Simulation Laboratory	PC	4	0	0	4	2
8.	PS7212	Technical Seminar	EEC	2	0	0	2	1
			TOTAL	**24**	**18**	**0**	**6**	**21**

Attested

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SEMESTER - III

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	PS7301	Advanced Power System Dynamics	PC	3	3	0	0	3
2.		Elective IV	PE	3	3	0	0	3
3.		Elective V	PE	3	3	0	0	3
PRACTICALS								
4.	PS7311	Project Work Phase I	EEC	12	0	0	12	6
			TOTAL	**21**	**9**	**0**	**12**	**15**

SEMESTER - IV

Sl. No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
PRACTICALS								
1.	PS7411	Project Work Phase II	EEC	24	0	0	24	12
			TOTAL	**24**	**0**	**0**	**24**	**12**

TOTAL NO. OF CREDITS: 70

ANNA UNIVERSITY, CHENNAI
UNIVERSITY DEPARTMENTS
REGULATIONS – 2015
CHOICE BASED CREDIT SYSTEM
M.E. POWER SYSTEMS ENGINEERING (PART TIME)
CURRICULA AND SYLLABI I TO VI SEMESTERS

SEMESTER - I

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	MA7156	Applied Mathematics for Electrical Engineers	FC	4	4	0	0	4
2.	PS7151	Advanced Power System Analysis	PC	4	4	0	0	4
3.	PE7152	Analysis of Electrical Machines	PC	3	3	0	0	3
			TOTAL	**11**	**11**	**0**	**0**	**11**

SEMESTER - II

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	PS7251	Advanced Power System Protection	PC	3	3	0	0	3
2.	PS7252	Analysis and Computation of Electromagnetic Transients in Power Systems	PC	3	3	0	0	3
3.	PS7254	Restructured Power System	PC	3	3	0	0	3
			TOTAL	**9**	**9**	**0**	**0**	**9**

SEMESTER - III

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	PS7101	Power System Operation and Control	PC	3	3	0	0	3
2.	PS7152	Power System Dynamics	PC	3	3	0	0	3
3.		Elective I	PE	3	3	0	0	3
PRACTICALS								
4.	PS7111	Power System Simulation Laboratory	PC	4	0	0	4	2
			TOTAL	**13**	**9**	**0**	**4**	**11**

Attested

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SEMESTER - IV

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	PS7253	Flexible AC Transmission Systems	PC	3	3	0	0	3
2.		Elective II	PE	3	3	0	0	3
3.		Elective III	PE	3	3	0	0	3
PRACTICALS								
4.	PS7211	Advanced Power System Simulation Laboratory	PC	4	0	0	4	2
5.	PS7212	Technical Seminar	EEC	2	0	0	2	1
			TOTAL	**15**	**9**	**0**	**6**	**12**

SEMESTER - V

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	PS7301	Advanced Power System Dynamics	PC	3	3	0	0	3
2.		Elective IV	PE	3	3	0	0	3
3.		Elective V	PE	3	3	0	0	3
PRACTICALS								
4.	PS7311	Project Work Phase I	EEC	12	0	0	12	6
			TOTAL	**21**	**9**	**0**	**12**	**15**

SEMESTER - VI

Sl. No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
PRACTICALS								
1.	PS7411	Project Work Phase II	EEC	24	0	0	24	12
			TOTAL	**24**	**0**	**0**	**24**	**12**

TOTAL NO. OF CREDITS: 70

FOUNDATION COURSES (FC)

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.		Applied Mathematics for Electrical Engineers	FC	4	4	0	0	4

PROFESSIONAL CORE (PC)

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.		Advanced Power System Analysis	PC	4	4	0	0	4
2.		Power System Operation and Control	PC	3	3	0	0	3
3.		Power System Dynamics	PC	3	3	0	0	3
4.		Analysis of Electrical Machines	PC	3	3	0	0	3
5.		Power System Simulation Laboratory	PC	4	0	0	4	2
6.		Analysis and Computation of Electromagnetic Transients in Power Systems	PC	3	3	0	0	3
7.		Advanced Power System Protection	PC	3	3	0	0	3
8.		Flexible AC Transmission Systems	PC	3	3	0	0	3
9.		Restructured Power System	PC	3	3	0	0	3
10.		Advanced Power System Simulation Laboratory	PC	4	0	0	4	2
11.		Advanced Power System Dynamics	PC	3	3	0	0	3

PROFESSIONAL ELECTIVES (PE)

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	CO7151	Control System Design	PE	4	4	0	0	4
2.	CO7152	Soft Computing Techniques	PE	3	3	0	0	3
3.	CO7076	System Theory	PE	3	3	0	0	3
4.	PW7072	Electric Vehicles and Power Management	PE	3	3	0	0	3
5.	PW7151	Distribution Systems Management and Automation	PE	3	3	0	0	3
6.	PE7151	Analysis and Design of Power Converters	PE	4	4	0	0	4
7.	PS7255	Smart Grids	PE	3	3	0	0	3
8.	PW7076	Urban and Rural Energy Management	PE	3	3	0	0	3
9.	PW7251	SCADA System and Applications Management	PE	3	3	0	0	3
10.	PW7073	Electricity Market Analysis	PE	3	3	0	0	3
11.	HV7251	Principles of Electric Power Transmission	PE	3	3	0	0	3
12.	HV7073	Electromagnetic Interference and Compatibility	PE	3	3	0	0	3
13.	PE7351	Special Electrical Machines	PE	3	3	0	0	3
14.	PE7251	Microcontroller and DSP Based System Design	PE	4	4	0	0	4
15.	PE7073	Power Quality	PE	3	3	0	0	3
16.	PE7252	Modelling and Design of SMPS	PE	3	3	0	0	3
17.	CO7251	Non Linear Control	PE	3	3	0	0	3
18.	PE7071	Nonlinear Dynamics for Power Electronic Circuits	PE	3	3	0	0	3
19.	PE7072	Power Electronics for Renewable Energy Systems	PE	3	3	0	0	3
20.	CO7075	System Identification and Adaptive Control	PE	3	3	0	0	3
21.	CO7074	Robust Control	PE	3	3	0	0	3
22.	PS7073	Optimisation Techniques	PE	3	3	0	0	3
23.	PS7074	Solar and Energy Storage System	PE	3	3	0	0	3
24.	PS7071	Distributed Generation and Micro Grid	PE	3	3	0	0	3
25.	PW7351	Energy Management and Auditing	PE	3	3	0	0	3

26.	PS7072	High Voltage Direct Current Transmission	PE	3	3	0	0	3
27.	PS7075	Wind Energy Conversion System	PE	3	3	0	0	3
28.	PS7001	Power System Planning and Reliability	PE	3	3	0	0	3
29.	ET7351	Distributed Embedded Computing	PE	3	3	0	0	3
30.	ET7074	MEMS Technology	PE	3	3	0	0	3
31.	HV7072	Design of Substations	PE	3	3	0	0	3
32.	PW7201	Grid Integration of Renewable Energy Sources	PE	3	3	0	0	3

EMPLOYABILITY ENHANCEMENT COURSES (EEC)

S.No	Course Code	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.		Technical Seminar	EEC	2	0	0	2	1
2.		Project Work Phase I	EEC	12	0	0	12	6
3.		Project Work Phase II	EEC	24	0	0	24	12

MA7156 APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS **LT P C**
4 0 0 4

OBJECTIVES:

- To develop the ability to apply the concepts of Matrix theory and Linear programming in Electrical Engineering problems.
- To achieve an understanding of the basic concepts of one dimensional random variables and apply in electrical engineering problems.
- To familiarize the students in calculus of variations and solve problems using Fourier transforms associated with engineering applications..

UNIT I MATRIX THEORY **12**
The Cholesky decomposition - Generalized Eigen vectors, Canonical basis - QR factorization - Least squares method - Singular value decomposition

UNIT II CALCULUS OF VARIATIONS **12**
Concept of variation and its properties – Euler's equation – Functional dependant on first and higher order derivatives – Functionals dependant on functions of several independent variables – Variational problems with moving boundaries – problems with constraints - Direct methods: Ritz and Kantorovich methods

UNIT III ONE DIMENSIONAL RANDOM VARIABLES **12**
Random variables - Probability function – moments – moment generating functions and their properties – Binomial, Poisson, Geometric, Uniform, Exponential, Gamma and Normal distributions – Function of a Random Variable

UNIT IV LINEAR PROGRAMMING **12**
Formulation – Graphical solution – Simplex method – Two phase method - Transportation and Assignment Models

UNIT V FOURIER SERIES **12**
Fourier Trigonometric series: Periodic function as power signals – Convergence of series – Even and odd function: cosine and sine series – Non-periodic function: Extension to other intervals - Power signals: Exponential Fourier series – Parseval's theorem and power spectrum – Eigen value problems and orthogonal functions – Regular Sturm-Liouville systems – Generalized Fourier series

TOTAL: 60 PERIODS

BOOKS FOR STUDY:

1. Richard Bronson, "Matrix Operation", Schaum's outline series, 2nd Edition, McGraw Hill, 2011.
2. Gupta, A.S., Calculus of Variations with Applications, Prentice Hall of India Pvt. Ltd., New Delhi, 1997.
3. Oliver C. Ibe, "Fundamentals of Applied Probability and Random Processes, Academic Press, (An imprint of Elsevier), 2010.
4. Taha, H.A., "Operations Research, An introduction", 10th edition, Pearson education, New Delhi, 2010.

5. Andrews L.C. and Phillips R.L., Mathematical Techniques for Engineers and Scientists, Prentice Hall of India Pvt.Ltd., New Delhi, 2005.

REFERENCES

1. Elsgolts, L., Differential Equations and the Calculus of Variations, MIR Publishers, Moscow, 1973.
2. Grewal, B.S., Higher Engineering Mathematics, 42nd edition, Khanna Publishers, 2012.
3. O'Neil, P.V., Advanced Engineering Mathematics, Thomson Asia Pvt. Ltd., Singapore, 2003.
4. Johnson R. A. and Gupta C. B., "Miller & Freund's Probability and Statistics for Engineers", Pearson Education, Asia, 7th Edition, 2007.

PE7152 ANALYSIS OF ELECTRICAL MACHINES L T P C
3 0 0 3

OBJECTIVES:

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

UNITI PRINCIPLES OF ELECTROMAGNETIC ENERGY CONVERSION 9

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

UNIT II DC MACHINES 9

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

UNIT III REFERENCE FRAME THEORY 9

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

UNIT IV INDUCTION MACHINES 9

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

UNIT V SYNCHRONOUS MACHINES **9**

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

TOTAL : 45 PERIODS

OUTCOMES:

- Ability to acquire and apply knowledge of mathematics and converter/machine dynamics in Electrical engineering.
- Ability to model and analyze power electronic systems and equipment using computational software.
- Ability to formulate, design, simulate power supplies for generic load and for machine loads.
- Ability to optimally design magnetics required in power supplies and drive systems.

TEXT BOOKS

1. Paul C.Krause, Oleg Wasyzczuk, Scott S, Sudhoff, "Analysis of Electric Machinery and Drive Systems", John Wiley, Second Edition, 2010.

REFERENCES

1. P S Bimbhra, "Generalized Theory of Electrical Machines", Khanna Publishers, 2008.
2. A.E, Fitzgerald, Charles Kingsley, Jr, and Stephan D, Umanx, " Electric Machinery", Tata McGraw Hill, 5th Edition, 1992.

PS7101	POWER SYSTEM OPERATION AND CONTROL	L T P C
		3 0 0 3

COURSE OBJECTIVES

- To impart knowledge on the need of state estimation and its role in the day-today operation of power system.
- To provide knowledge about Hydro-thermal scheduling, Unit commitment and solution techniques.
- To analyze the power system security using sensitivity factors.

UNIT I INTRODUCTION **9**

Overview of system operation: Load forecasting - Techniques of forecasting, basics of power system operation and control - Review of Active and Reactive Power flow and SCADA.

UNIT II STATE ESTIMATION 9

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

UNIT III HYDROTHERMAL SCHEDULING PROBLEM 9

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

UNIT 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, co-ordination equations without loss and with loss, solution by direct method and λ-iteration method, Base point and participation factors, Economic dispatch controller added to LFC control.

UNIT V POWER SYSTEM SECURITY 9

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

TOTAL: 45 PERIODS

OUTCOMES

- Learners will be able to understand system load variations and get an overview of power system operations.
- Learners will be exposed to power system state estimation.
- Learners will attain knowledge about hydrothermal scheduling.
- Learners will understand the significance of unit commitment and different solution methods.
- Learners will be able to analyze power system security.

TEXTBOOKS

1. Allen.J.Wood and Bruce F.Wollenberg, ‘Power Generation, Operation and Control’, John Wiley & Sons, Inc., 2003.
2. P. Kundur, ‘Power System Stability & Control’, McGraw Hill Publications,USA, 1994
3. Ali Abur & Antinio Gomez Exposito, ’Power System State Estimation Theory & Implementation’, Marcel Dekker, Inc., Newyork,USA,2004.

REFERENCES:

1. Olle. I. Elgerd, ‘Electric Energy Systems Theory – An Introduction’, Tata McGraw Hill Publishing Company Ltd,New Delhi, Second Edition, 2003.
2. D.P. Kothari and I.J. Nagrath, ‘Modern Power System Analysis’, Third Edition, Tata McGraw Hill Publishing Company Limited,New Delhi, 2003.
3. L.L. Grigsby, ‘The Electric Power Engineering, Hand Book’, CRC Press & IEEE Press, 2001

PS7151 ADVANCED POWER SYSTEM ANALYSIS

L	T	P	C
4	0	0	4

COURSE OBJECTIVES

- To introduce different techniques of dealing with sparse matrix for large scale power systems.
- To impart in-depth knowledge on different methods of power flow solutions.
- To perform optimal power flow solutions in detail.
- To perform short circuit fault analysis and understand the consequence of different type of faults.

UNIT I SOLUTION TECHNIQUE 12

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 12

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

UNIT III OPTIMAL POWER FLOW 12

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

UNIT IV SHORT CIRCUIT ANALYSIS 12

Formation of bus impedance matrix with mutual coupling (single phase basis and three phase basis) - Computer method for fault analysis using Z_{BUS} 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 DISTRIBUTION LOAD FLOW 12

Need for distribution load flow-Forward, Backward Sweep method – Iterative distribution load flow -3-phase load flow- distributed generation.

TOTAL: 60 PERIODS

OUTCOME

- Learners are equipped with the power system studies that needed for the transmission system planning.
- Learners will be able to analyse the impact of distributed generators on the performance of distribution system

TEXTBOOKS

1. G W Stagg , A.H El. Abiad "Computer Methods in Power System Analysis", M cGraw Hill, 1968.
2. P.Kundur, "Power System Stability and Control", McGraw Hill, 1994.

REFERENCES:

1. A.J.Wood and B.F.Wollenberg,"Power Generation Operation and Control", John Wiley and sons, New York, 1996.
2. W.F.Tinney and W.S.Meyer, "Solution of Large Sparse System by Ordered Triangular Factorization" IEEE Trans. on Automatic Control, Vol : AC-18, pp:333-346, Aug 1973.
3. 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.
4. M.A.Pai," Computer Techniques in Power System Analysis",Tata McGraw-Hill Publishing Company Limited, New Delhi, 2006
5. D. Thukara,H.M. Wijekoon Banda & Jovitha Jerome, 'A robust three phase power flow algorithm for radial distribution systems' ,Electric Power Systems Research 50 (1999) 227–236

PS7152	POWER SYSTEM DYNAMICS	L T P C
		3 0 0 3

COURSE OBJECTIVES

- To impart knowledge on dynamic modelling of a synchronous machine in detail
- To describe the modelling of excitation and speed governing system in detail.
- To understand the fundamental concepts of stability of dynamic systems and its classification
- To understand and enhance small signal stability problem of power systems.

UNIT I SYNCHRONOUS MACHINE MODELLING 9

Schematic Diagram, Physical Description: armature and field structure, machines with multiple pole pairs, mmf waveforms, direct and quadrature axes, Mathematical Description of a Synchronous Machine: Basic equations of a synchronous machine: stator circuit equations, stator self, stator mutual and stator to rotor mutual inductances, dq0 Transformation: flux linkage and voltage equations for stator and rotor in dq0 coordinates, electrical power and torque, physical interpretation of dq0 transformation, Per Unit Representations: L_{ad}-reciprocal per unit system and that from power-invariant form of Park's transformation; Equivalent Circuits for direct and quadrature axes, Steady-state Analysis: Voltage, current and flux-linkage relationships, Phasor representation, Rotor angle, Steady-state equivalent circuit, Computation of steady-state values, Equations of Motion: Swing Equation, calculation of inertia constant, Representation in system studies, Synchronous Machine Representation in Stability Studies: Simplifications for large-scale studies : Neglect of stator *p* terms and speed variations, Simplified model with amortisseurs neglected: two-axis model with amortisseur windings neglected, classical model.

UNIT II MODELLING OF EXCITATION AND SPEED GOVERNING SYSTEMS 9

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

UNIT III SMALL-SIGNAL STABILITY ANALYSIS WITHOUT CONTROLLERS 9

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

UNIT IV SMALL-SIGNAL STABILITY ANALYSIS WITH CONTROLLERS 9

Effects Of Excitation System: Equations with definitions of appropriate K-constants and simple thyristor excitation system and AVR, block diagram with the excitation system, analysis of effect of AVR on synchronizing and damping components using a numerical example, Power System Stabiliser: Block diagram with AVR and PSS, Illustration of principle of PSS application with numerical example, Block diagram of PSS with description, system state matrix including PSS, analysis of stability with numerical a example. Multi-Machine Configuration: Equations in a common reference frame, equations in individual machine rotor coordinates, illustration of formation of system state matrix for a two-machine system with classical models for synchronous machines, illustration of stability analysis using a numerical example. Principle behind small-signal stability improvement methods: delta-omega and delta P-omega stabilizers.

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 stabilizer gain – Stabilizer limits

TOTAL: 45 PERIODS

OUTCOMES

- Learners will be able to understand on dynamic modelling of synchronous machine.
- Learners will be able to understand the modeling of excitation and speed governing system for stability analysis.
- Learners will attain knowledge about stability of dynamic systems.
- Learners will understand the significance about small signal stability analysis with controllers.
- Learners will understand the enhancement of small signal stability.

TEXT BOOKS:

1. R.Ramunujam," Power System Dynamics Analysis and Simulation, PHI Learning Private Limited, New Delhi, 2009
2. P. Kundur, "Power System Stability and Control", McGraw-Hill, 1993.

REFERENCES:

1. P. W. Sauer and M. A. Pai," Power System Dynamics and Stability", Stipes Publishing Co, 2007
2. IEEE Committee Report, "Dynamic Models for Steam and Hydro Turbines in Power System Studies", IEEE Trans., Vol.PAS-92, pp 1904-1915, November/December, 1973.on Turbine-Governor Model.
3. P.M Anderson and A.A Fouad, "Power System Control and Stability", Iowa State University Press, Ames, Iowa, 1978.

PS7111 POWER SYSTEM SIMULATION LABORATORY **LT P C**
0 0 4 2

COURSE OBJECTIVES

- To have hands on experience on various system studies and different techniques used for system planning using software packages.

1. Power flow analysis by Newton-Raphson method and Fast decoupled method
2. Distance Protection
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. Familiarization of Relay Test Kit with testing of Numerical Over current Relay Simulation and Implementation of Voltage Source Inverter
7. Digital Over Current Relay Setting and Relay Coordination using Suitable software packages
8. Co-ordination of over-current and distance relays for radial line protection.
9. State Estimation (DC)
10. Study of Directional over current feature with Numerical Relay.

TOTAL: 60 PERIODS

OUTCOMES

- Learners will be able to analyze the power flow using Newton-Raphson method and Fast decoupled method.
- Learners will be able to perform contingency analysis & economic dispatch
- Learners will be able to Set Digital Over Current Relay and Coordinate Relay

PS7251 ADVANCED POWER SYSTEM PROTECTION L T P C
3 0 0 3

COURSE OBJECTIVES

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

UNIT I OVER CURRENT & EARTH FAULT PROTECTION 9

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

UNIT II TRANSFORMER & BUSBAR PROTECTION 13

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

UNIT III DISTANCE AND CARRIER PROTECTION OF TRANSMISSION LINES 9

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

UNIT IV GENERATOR PROTECTION 8

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

UNIT V SUBSTATION AUTOMATION 6

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

TOTAL: 45 PERIODS

OUTCOME

- Learners will be able to understand the various schemes available in Transformer protection
- Learners will have knowledge on Overcurrent protection.
- Learners will attain knowledge about Distance and Carrier protection in transmission lines.
- Learners will understand the concepts of Bus bar protection.
- Learners will attain basic knowledge on substation automation.

TEXTBOOKS

1. Y.G. Paithankar and S.R Bhide, "Fundamentals of Power System Protection", Prentice-Hall of India, 2003
2. Badri Ram and D.N. Vishwakarma, "Power System Protection and Switchgear", Tata McGraw- Hill Publishing Company, 2002.

REFERENCES

1. P.Kundur, "Power System Stability and Control", McGraw-Hill, 1993.
2. Protective Relaying for Power System II Stanley Horowitz,IEEE press , New York, 2008
3. Network Protection & Automation Guide, Edition May 2011 – Alstom Grid.
4. T.S.M. Rao, Digital Relay / Numerical relays, Tata McGraw Hill, New Delhi, 1989

PS7252	ANALYSIS AND COMPUTATION OF ELECTROMAGNETIC TRANSIENTS IN POWER SYSTEMS	L T P C 3 0 0 3

COURSE OBJECTIVE

- To impart knowledge on the travelling wave phenomena
- To impart knowledge on the modeling of overhead lines, underground cables, transformers.
- To analyze about power system transients.

UNIT I REVIEW OF TRAVELLING WAVE PHENOMENA 9

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

UNIT II PARAMETERS AND MODELLING OF 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 modelling.

UNIT III PARAMETERS AND MODELLING 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 IV PARAMETERS AND MODELLING OF TRANSFORMERS 9

Transformer modelling guidelines for transient phenomena – Generalization of [R]-[ωL] model single phase N-coil transformer-Generalization of $[R]-[\omega L]^{-1}$ model single phase N-coil transformer-Inverse Inductance Matrix representation of three-phase N-coil transformers- inclusion of exciting current- modelling of autotransformers.

UNIT V COMPUTATION OF POWER SYSTEM TRANSIENTS 9

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

TOTAL : 45 PERIODS

OUTCOMES

- Learners will be able to model over head lines, cables and transformers.
- Learners will be able to analyze power system transients.

TEXT BOOKS

1. Allan Greenwood, "*Electrical Transients in Power System*", Wiley & Sons Inc. New York, 1991.
2. R. Ramanujam, *Computational Electromagnetic Transients: Modelling, Solution Methods and Simulation*, I.K. International Publishing House Pvt. Ltd, New Delhi -110 016, ISBN 978-93-82332-74-9, 2014; email: info@ikinternational.com

REFERENCES

1. Rakosh Das Begamudre, "*Extra High Voltage AC Transmission Engineering*", (Second edition) Newage International (P) Ltd., New Delhi, 1990.
2. Naidu M S and Kamaraju V, "*High Voltage Engineering*", Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2004.

PS7253 FLEXIBLE AC TRANSMISSION SYSTEMS LT P C
3 0 0 3

COURSE OBJECTIVES

- To emphasis the need for FACTS controllers.
- To learn the characteristics, applications and modelling of series and shunt FACTS controllers.
- To analyze the interaction of different FACTS controller and perform control coordination

UNIT I INTRODUCTION 9

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

UNIT II STATIC VAR COMPENSATOR (SVC) 9

Configuration of SVC- voltage regulation by SVC- Modelling of SVC for load flow analysis- Modelling of SVC for stability studies-Design of SVC to regulate the mid-point voltage of a SMIB system- Applications: transient stability enhancement and power oscillation damping of SMIB system with SVC connected at the mid-point of the line.

UNIT III THYRISTOR AND GTO THYRISTOR CONTROLLED SERIES CAPACITORS (TCSC and GCSC) 9

Concepts of Controlled Series Compensation – Operation of TCSC and GCSC- Analysis of TCSC-GCSC – Modelling of TCSC and GCSC for load flow studies- modelling TCSC and GCSC for stability studied- Applications of TCSC and GCSC

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 and IPFC)- Modelling of UPFC and IPFC for load flow and transient stability studies- Applications.

UNIT V CONTROLLERS AND THEIR COORDINATION 9

FACTS Controller interactions – SVC–SVC interaction - co-ordination of multiple controllers using linear control techniques – Quantitative treatment of control coordination.

TOTAL : 45 PERIODS

OUTCOMES

- Learners will be able to refresh on basics of power transmission networks and need for FACTS controllers
- Learners will be able to explain about static var compensator in detail
- Learners will attain knowledge about Controlled Series Compensation
- Learners will understand the significance about different voltage source converter based facts controllers
- Learners will be able to analyze on FACTS controller interaction and control coordination

Attested
DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

TEXT BOOKS

1. Mohan Mathur, R., Rajiv. K. Varma, “Thyristor – Based Facts Controllers for Electrical Transmission Systems”, IEEE press and John Wiley & Sons, Inc.
2. K.R.Padiyar,” FACTS Controllers in Power Transmission and Distribution”, New Age International(P) Ltd., Publishers, New Delhi, Reprint 2008,

REFERENCES:

1. A.T.John, “Flexible AC Transmission System”, Institution of Electrical and Electronic Engineers (IEEE), 1999.
2. Narain G.Hingorani, Laszio. Gyugyl, “Understanding FACTS Concepts and Technology of Flexible AC Transmission System”, Standard Publishers, Delhi 2001.
3. V.K.Sood, “HVDC and FACTS controllers- Applications of Static Converters in Power System”, 2004, Kluwer Academic Publishers.

PS7254	**RESTRUCTURED POWER SYSTEM**	**LT P C**
		3 0 0 3

COURSE OBJECTIVES

- To introduce the restructuring of power industry and market models.
- To impart knowledge on fundamental concepts of congestion management.
- To analyze the concepts of locational marginal pricing and financial transmission rights.
- To Illustrate about various power sectors in India

UNIT I INTRODUCTION TO RESTRUCTURING OF POWER INDUSTRY 9

Introduction: Deregulation of power industry, Restructuring process, Issues involved in deregulation, Deregulation of various power systems – Fundamentals of Economics: Consumer behavior, Supplier behavior, Market equilibrium, Short and long run costs, Various costs of production – Market models: Market models based on Contractual arrangements, Comparison of various market models, Electricity vis – a – vis other commodities, Market architecture, Case study.

UNIT II TRANSMISSION CONGESTION MANAGEMENT 9

Introduction: Definition of Congestion, reasons for transfer capability limitation, Importance of congestion management, Features of congestion management – Classification of congestion management methods – Calculation of ATC - Non – market methods – Market methods – Nodal pricing – Inter zonal and Intra zonal congestion management – Price area congestion management – Capacity alleviation method.

UNIT III LOCATIONAL MARGINAL PRICES AND FINANCIAL TRANSMISSION RIGHTS 9

Mathematical preliminaries: - Locational marginal pricing– Lossless DCOPF model for LMP calculation – Loss compensated DCOPF model for LMP calculation – ACOPF model for LMP calculation – Financial Transmission rights – Risk hedging functionality - Simultaneous feasibility test and revenue adequency – FTR issuance process: FTR auction, FTR allocation –

Treatment of revenue shortfall – Secondary trading of FTRs – Flow gate rights – FTR and market power - FTR and merchant transmission investment.

UNIT IV ANCILLARY SERVICE MANAGEMENT AND PRICING OF TRANSMISSION NETWORK 9

Introduction of ancillary services – Types of Ancillary services – Classification of Ancillary services – Load generation balancing related services – Voltage control and reactive power support devices – Black start capability service - How to obtain ancillary service –Co-optimization of energy and reserve services - International comparison Transmission pricing – Principles – Classification – Rolled in transmission pricing methods – Marginal transmission pricing paradigm – Composite pricing paradigm – Merits and demerits of different paradigm.

UNIT V REFORMS IN INDIAN POWER SECTOR 9

Introduction – Framework of Indian power sector – Reform initiatives - Availability based tariff – Electricity act 2003 – Open access issues – Power exchange – Reforms in the near future

TOTAL : 45 PERIODS

OUTCOMES

- Learners will have knowledge on restructuring of power industry
- Learners will understand basics of congestion management
- Learners will attain knowledge about locational margin prices and financial transmission rights
- Learners will understand the significance ancillary services and pricing of transmission network
- Learners will have knowledge on the various power sectors in India

TEXT BOOKS

1. Mohammad Shahidehpour, Muwaffaq Alomoush, Marcel Dekker, "Restructured electrical power systems: operation, trading and volatility" Pub., 2001
2. Kankar Bhattacharya, Jaap E. Daadler, Math H.J. Boolen," Operation of restructured power systems", Kluwer Academic Pub., 2001.

REFERENCES

1. Sally Hunt," Making competition work in electricity", , John Willey and Sons Inc. 2002
2. Steven Stoft," Power system economics: designing markets for electricity", John Wiley & Sons, 2002.

PS7211 ADVANCED POWER SYSTEM SIMULATION LABORATORY

L T P C
0 0 4 2

COURSE OBJECTIVES

- To analyze the effect of FACTS controllers by performing steady state analysis.
- To have hands on experience on different wind energy conversion technologies.

1 Small-signal stability analysis of single machine-infinite bus system using classical machine model
2 Small-signal stability analysis of multi-machine configuration with classical machine model
3 Induction motor starting analysis
4 Load flow analysis of two-bus system with STATCOM
5 Transient analysis of two-bus system with STATCOM
6 Available Transfer Capability calculation using an existing load flow program
7 Study of variable speed wind energy conversion system- DFIG
8 Study of variable speed wind energy conversion system- PMSG
9 Computation of harmonic indices generated by a rectifier feeding a R-L load
10 Design of active filter for mitigating harmonics.
11 Analysis of switching surge using EMTP : Energisation of a long distributed-parameter line
12 Analysis of switching surge using EMTP : Computation of transient recovery voltage
13 Study of Numerical Transformer / Distance Protection with Relay test kit.

TOTAL: 60 PERIODS

OUTCOMES

- Students are able to gain Hands on experience on various power system dynamic studies using own program and validation of results using software packages.

PS7301 ADVANCED POWER SYSTEM DYNAMICS

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COURSE OBJECTIVES

- To perform transient stability analysis using unified algorithm.
- To impart knowledge on sub-synchronous resonance and oscillations.
- To analyze voltage stability problem in power system.
- 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 POWERSYSTEMS 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

Subsysnchronous Resonance (SSR) – Types of SSR - Characteristics of series –

Compensated transmission systems –Modelling of turbine-generator-trasmission 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 nearby DC converters.

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 [1] 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.

TOTAL: 45 PERIODS

OUTCOMES

- Learners will be able to understand the various schemes available in Transformer protection
- Learners will have knowledge on Over current protection.
- Learners will attain knowledge about Distance and Carrier protection in transmission lines.
- Learners will understand the concepts of Busbar protection.
- Learners will attain basic knowledge on numerical protection techniques

TEXT BOOKS

1. R.Ramnujam," 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.

REFERENCES

1. P. Kundur, Power System Stability and Control, McGraw-Hill, 1993.
2. H.W. Dommel and N.Sato, "Fast Transient Stability Solutions," IEEE Trans., Vol. PAS-91, pp, 1643-1650, July/August 1972.
3. Roderick J.Frowd and J. C. Giri, "Transient stability and Long term dynamics unified", IEEE Trans., Vol 101, No. 10, October 1982.
4. 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 Pg.129 to 138.

CO7151 CONTROL SYSTEM DESIGN **L T P C**
4 0 0 4

COURSE OBJECTIVES

- To impart knowledge on continuous system and discrete system and effect of sampling.
- To impart knowledge on design of controllers using root-locus and frequency domain techniques.
- To educate on concept of state space and design of controllers and observers.
- To introduce the techniques of extending the theory on continuous systems to discrete time systems.
- To introduce the linear quadratic regulator and estimation in the presence of Noise.

UNIT I CONTINUOUS AND DISCRETE SYSTEMS 12

Review of continuous systems- Need for discretization-comparison between discrete and analog system. Sample and Hold devices - Effect of sampling on transfer function and state models- Analysis.

UNIT II ROOT LOCUS DESIGN 12

Design specifications-In Continuous domain - Limitations- Controller structure- Multiple degrees of freedom- PID controllers and Lag-lead compensators- Root locus design-Discretization & Direct discrete design.

UNIT III DESIGN IN FREQUENCY RESPONSE BASED DESIGN 12

Lag-lead compensators – Design using Bode plots- use of Nichole's chart and Routh-hurwitz Criterion-Jury's stability test- Digital design.

UNIT IV STATE VARIABLE DESIGN 12

Pole Assignment Design- state and output feedback-observers - Estimated state feedback - Design examples (continuous & Discrete).

UNIT V LQR AND LQG DESIGN 12

Formulation of LQR problem- Pontryagin's minimum principle and Hamiltonian solutions-Ricatti's equation – Optimal estimation- Kalman filter –solution to continuous and discrete systems - Design examples.

TOTAL: 60 PERIODS

COURSE OUTCOME

- Ability to understand the specification, limitation and structure of controllers.
- Ability to design a controller using Root-locus and Frequency Domain technique.
- Acquire knowledge on state space and ability to design a controller and observer.
- Ability to design LQR and LQG for a system.

REFERENCES

1. G. F. Franklin, J. D. Powell and M Workman, "Digital Control of Dynamic Systems", PHI (Pearson), 2002.
2. Graham C. Goodwin, Stefan F. Graebe and Mario E. Salgado "Control system Design", PHI (Pearson), 2003.
3. M.Gopal "Digital Control and State variable methods" Mc graw hill 4^{th} edition, 2012.
4. Benjamin C. Kuo "Digital control systems", Oxford University Press, 2004
5. M. Gopal "Modern control system Theory" New Age International, 2005.
6. J.J. D'Azzo, C.H. Houpis and s.N Sheldon,'Linear Control system analysis and design with MATLAB,' Taylor and Francis,2009.

CO7152 **SOFT COMPUTING TECHNIQUES** **LT P C**
3 0 0 3

COURSE OBJECTIVES

- To review the fundamentals of ANN and fuzzy set theory.
- To make the students understand the use of ANN for modeling and control of non-linear system and to get familiarized with the ANN tool box.
- To impart knowledge of using Fuzzy logic for modeling and control of non-linear systems and get familiarized with the FLC tool box.
- To make the students to understand the use of optimization techniques.
- To familiarize the students on various hybrid control schemes, P.S.O and get familiarized with the ANFIS tool box.

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

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

UNIT II NEURAL NETWORKS FOR MODELLING AND CONTROL 9

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

UNIT III FUZZY LOGIC FOR MODELLING AND CONTROL 9

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

UNIT IV GENETIC ALGORITHM 9

Basic concept of Genetic algorithm and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using genetic algorithm. Concept on some other search techniques like Tabu search, Ant-colony search and Particle Swarm Optimization.

UNIT V HYBRID CONTROL SCHEMES 9

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

TOTAL : 45 PERIODS

COURSE OUTCOME

Students,

- Will be able to know the basic ANN architectures, algorithms and their limitations.
- Also will be able to know the different operations on the fuzzy sets.
- Will be capable of developing ANN based models and control schemes for non-linear system.
- Will get expertise in the use of different ANN structures and online training algorithm.
- Will be knowledgeable to use Fuzzy logic for modeling and control of non-linear systems.
- Will be competent to use hybrid control schemes and P.S.O.

REFERENCES

1. Laurene V.Fausett, “Fundamentals of Neural Networks, Architecture, Algorithms, and Applications”, Pearson Education, 2008.
2. Timothy J.Ross, “Fuzzy Logic with Engineering Applications”, Wiley, Third Edition, 2010.
3. David E.Goldberg, “Genetic Algorithms in Search, Optimization, and Machine Learning”, Pearson Education, 2009.
4. W.T.Miller, R.S.Sutton and P.J.Webrose, “Neural Networks for Control”, MIT Press, 1996.
5. George J.Klir and Bo Yuan, “Fuzzy Sets and Fuzzy Logic: Theory and Applications”, Prentice Hall, First Edition, 1995.
6. N.P Padhy, S.P. Simon “Soft Computing With MATLAB Programming”,OXFORD print Feburary 2015.

CO7076 SYSTEM THEORY L T P C

3 0 0 3

COURSE OBJECTIVES

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

UNIT I STATE VARIABLE REPRESENTATION 9

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

UNIT II SOLUTION OF STATE EQUATIONS 9

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

UNIT III CONTROLLABILITY AND OBSERVABILITY 9

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

UNIT IV STABILTY 9

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

UNIT V MODAL CONTROL 9

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

TOTAL : 45 PERIODS

COURSE OUTCOME

- Acquire the concept of State-State equation for Dynamic Systems and understand the uniqueness of state model.
- Ability to differentiate the existence and uniqueness of Continuous time state equations.
- Ability to analyse the controllability and observability of a system.
- Acquire detail knowledge on stability analysis of Linear & Nonlinear Continuous Time Autonomous Systems.

REFERENCES:

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

PW7072 ELECTRIC VEHICLES AND POWER MANAGEMENT L T P C
3 0 0 3

COUSE OBJECTIVE:

- To understand the concept of electrical vehicles and its operations
- To understand the need for energy storage in hybrid vehicles
- To provide knowledge about various possible 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 CONTROL OF DC AND AC DRIVES 9

DC/DC chopper based four quadrant operations of DC drives – Inverter based V/f Operation (motoring and braking) of induction motor drive system – Induction motor and permanent motor based vector control operation – Switched reluctance motor (SRM) drives

UNIT IV BATTERY ENERGY STORAGE SYSTEM 9

Battery Basics, Different types, Battery Parameters, Battery modeling, Traction Batteries

UNIT V ALTERNATIVE ENERGY STORAGE SYSTEMS 9

Fuel cell – Characteristics- Types – hydrogen Storage Systems and Fuel cell EV – Ultra capacitors

TOTAL 45 PERIODS

OUTCOME:

- This course equips the student to understand the operation of Electric vehicles and various energy storage technologies for electrical vehicles.

REFERENCES

1. Iqbal Hussain, 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

PW7151 DISTRIBUTION SYSTEMS MANAGEMENT AND AUTOMATION L T P C

3 0 0 3

COURSE OBJECTIVE:

- To provide knowledge about management of distribution system and distribution automation
- To gain knowledge about planning and designing of distribution system
- To analyze power quality in distribution system

UNIT I INTRODUCTION 9

Overview of the distribution system, Importance of Distribution Systems, the Differences of Power Supply between Urban and Rural Area, Distribution system Consumer Classification

UNIT II DISTRIBUTION SYSTEM PLANNING 9

Factors effecting planning, present techniques, planning models(Short term planning, long term planning and dynamic planning), planning in the future, future nature of distribution planning, Role of computer in Distribution planning. Load forecast, Load characteristics and Load models.

UNIT III DISTRIBUTION SYSTEM DESIGN 9

Types of sub- transmission, Distribution substation, bus schemes, substation location, rating of substation, calculation of voltage drops with primary feeders and secondary feeders, uniformly distributed load and Non uniformly distributed load.

UNIT IV POWER QUALITY AND DISTRIBUTION SYSTEM PERFORMANCE ANALYSIS 9

Power quality problems in distribution systems, Power quality study as per IEEE and IEC standards, Distribution Feeder Analysis – the ladder Iterative technique, Power loss calculations and control measures. Distribution system voltage regulation: voltage control, Application of capacitors in Distribution system. Case study on TNEB distribution system

UNIT V DISTRIBUTION AUTOMATION 9

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

TOTAL: 45 PERIODS

OUTCOME:

- This course will equip students to have basic knowledge in distribution system management and automation and will enhance their capability of planning and designing of distribution system.

REFERENCES:

1. James Northcote – Green, Robert Wilson, "Control and Automation of Electrical Power Distribution Systems", CRC Press, New York, 2007.
2. Turan Gonen: .Electric Power Distribution System Engineering. McGraw Hill Company. 1986
3. M.V Deshpande: .Electrical Power System Design. Tata-McGraw Hill, 1966
4. IEEE Press: IEEE Recommended practice for Electric Power Distribution for Industrial Plants, published by IEEE, Inc., 1993

5. Pansini, Electrical Distribution Engineering, The Fairmont Press, Inc., 2007
6. Pabla H S.: .Electrical Power Distribution Systems.. Tata McGraw Hill. 2004
7. IEEE Standerd 739. Recommended Practice for Energy Conservation and Cost Effective Planning in Industrial Facilities. 1984
8. G H Heydt .Electric Power Quality. McGram Hill, 2007 Wilson K. Kazibwe and Musoke H Semdaula .Electric Power Quality Control Techniques.. Van Nostarand Reinhold New York, 2006

PE7151 ANALYSIS AND DESIGN OF POWER CONVERTERS **L T P C**
4 0 0 4

OBJECTIVES :

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

UNIT I SINGLE PHASE AC-DC CONVERTER 12

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

UNIT II THREE PHASE AC-DC CONVERTER 12

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

UNIT III SINGLE PHASE INVERTERS 12

Introduction to self-commutatedswitches : MOSFET and IGBT - Principle of operation of half and full bridge inverters – Performance parameters – Voltage control of single phase inverters using various PWM techniques – various harmonic elimination techniques – forced commutated Thyristor inverters – Design of UPS

UNIT IV THREE PHASE INVERTERS 12

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

UNIT V MODERN INVERTERS 12

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

TOTAL: 60 PERIODS

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OUTCOMES:

- Ability to acquire and apply knowledge of mathematics and converter/machine dynamics in Electrical engineering.
- Ability to model, analyze and understand power electronic systems and equipment using computational software.
- Ability to formulate, design, simulate power supplies for generic load and for machine loads.

TEXT BOOKS

1. Rashid M.H., “Power Electronics Circuits, Devices and Applications ", Prentice Hall India, Third Edition, New Delhi, 2004.
2. Jai P.Agrawal, “Power Electronics Systems”, Pearson Education, Second Edition, 2002.
3. Bimal K.Bose “Modern Power Electronics and AC Drives”, Pearson Education, Second Edition, 2003.
4. Ned Mohan,T.MUndeland and W.P Robbin, “Power Electronics: converters, Application and design” John Wiley and sons.Wiley India edition, 2006.
5. Philip T. krein, “Elements of Power Electronics” Oxford University Press -1998.

REFERENCES

1. P.C. Sen, “Modern Power Electronics”, Wheeler Publishing Co, First Edition, New Delhi, 1998.
2. P.S.Bimbra, “Power Electronics”, Khanna Publishers, Eleventh Edition, 2003.

PS7255	**SMART GRIDS**	**LT P C**
		3 0 0 3

COURSE OBJECTIVES

- To Study about Smart Grid technologies, different smart meters and advanced metering infrastructure.
- To familiarize the power quality management issues in Smart Grid.
- To familiarize the high performance computing for Smart Grid 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, National and International Initiatives in Smart Grid.

UNIT II SMART GRID TECHNOLOGIES (Transmission) 9

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

UNIT III SMART GRID TECHNOLOGIES (Distribution) 9

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

UNIT IV SMART METERS AND ADVANCED METERING INFRASTRUCTURE 9

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

UNIT V HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATIONS 9

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

TOTAL : 45 PERIODS

OUTCOMES

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

TEXT BOOKS

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.

REFERENCES*:*

1. Vehbi C. Güngör, 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.
2. Xi Fang, Satyajayant Misra, Guoliang Xue, and Dejun Yang “Smart Grid – The New and Improved Power Grid: A Survey” , IEEE Transaction on Smart Grids,

PW7076 URBAN AND RURAL ENERGY MANAGEMENT **L T P C**
3 0 0 3

COURSE OBJECTIVE:

- To give introduction about indian energy scenario
- To provide knowledge about urban and rural environment and its energy demand
- To understand the concept of green building and electric vehicle charging station

UNIT I INDIAN ENERGY SCENARIO 9

Commercial and non-commercial forms of energy, energy consumption pattern and Its variation as a function of time, energy resources available in India, urban and rural energy consumption, nuclear energy - promise and future, energy as a factor limiting growth, need for use of new and renewable energy sources.

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UNIT II URBAN ENVIRONMENT AND GREEN BUILDINGS 9

Patterns of fuel consumption: agricultural, domestic, industrial and community needs, Projection of energy demands, Optimization of use of various energy sources, Substitution of conventional energy sources by alternative sources and more efficient modern technologies Utility of Solar energy in buildings concepts of Solar Passive Cooling and Heating of Buildings Low Energy Cooling. Case studies of Solar Passive Cooled and Heated Buildings

UNIT III URBAN ELECTRIC VEHICLE CHARGING STATIONS 9

Electric vehicle charging stations- Integration of PHEV into Energy Networks – Impact on Distribution Systems – DC Fast Charging – Co-ordinated charging- V2G technology

UNIT IV THE RURAL ENERGY SITUATION 9

effects of Bio fuel use in rural India. Pollution and Health Ecological damage, Energy efficiency, the transition to modern energy, Rural Electrification policy.

UNIT V OPTION FOR RURAL ELECTRIFICATION 9

Cost Effectiveness and choice of options, Costs of Grid Supplies, Reducing initial investment costs by using appropriate design standards, Micro-grids supplied by diesel generators, Electricity Supplies from Renewable Energy Sources.

TOTAL: 45 PERIODS

OUTCOME:

- Students will get idea about utilization of energy in rural and urban areas

REFERENCES

1. Tools & methods for Integrated Resource Planning - Joel N.Swisher, Gilberto de Martino Jannzzi Robert Y. Red Linger,Publisher UNEP Collaborating Centre on Energy & Environment, RISO National Laboratory, Denmark, Nov. - 1997
2. Integrated Resource Planning & Demand Side Management through Regulation – 2002 sponsored by US AID. Integrated Energy Policy of India - 2006

PW7251 SCADA SYSTEM AND APPLICATIONS MANAGEMENT **L T P C**
3 0 0 3

COURSE OBJECTIVE:

- To understand about the SCADA system components and SCADA communication protocols
- To provide knowledge about SCADA applicatios in power system

UNIT I INTRODUCTION TO SCADA **9**

Evolution of SCADA, SCADA definitions, SCADA Functional requirements and Components, SCADA Hierarchical concept, SCADA architecture, General features, SCADA Applications, Benefits

UNIT II SCADA SYSTEM COMPONENTS **9**

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

UNIT III SCADA COMMUNICATION **9**

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

UNIT IV SCADA MONITORING AND CONTROL **9**

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

UNIT V SCADA APPLICATIONS IN POWER SYSTEM **9**

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

CASE STUDIES:

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

TOTAL: 45 PERIODS

OUTCOME:

- This course gives knowledge about various system components and communication protocols of SCADA system and its applications.

REFERENCES:

1. Stuart A. Boyer: SCADA-Supervisory Control and Data Acquisition, Instrument Society of America Publications,USA,2004
2. Gordon Clarke, Deon Reynders: Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems, Newnes Publications, Oxford, UK,2004
3. William T. Shaw, Cybersecurity for SCADA systems, PennWell Books, 2006

Attested

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4. David Bailey, Edwin Wright, Practical SCADA for industry, Newnes, 2003
5. Michael Wiebe, A guide to utility automation: AMR, SCADA, and IT systems for electric Power, PennWell 1999
6. Dieter K. Hammer, Lonnie R. Welch, Dieter K. Hammer, "Engineering of Distributed Control Systems", Nova Science Publishers, USA, 1st Edition, 2001

PW7073	ELECTRICITY MARKET ANALYSIS	L T P C
		3 0 0 3

COURSE OBJECTIVE:

- To provide brief introduction on restructuring of power system and various market models
- To provide knowledge about demand and price forecasting and price based unit commitment
- To provide knowledge about transmission congestion management and pricing
- To provide knowledge about electricity trading, generator asset valuation and risk management

UNIT I INTROUCTION OF RESTRUCTURING AND MARKET MODELS 9

Restructuring of Utilities- Different Models: PoolCo Model, Bilateral Contracts Model, Hybrid Model - Independent System Operator (ISO)- The Role of ISO - Power Exchange(PX): Market Clearing Price(MCP) - Market operations: Day-ahead and Hour-Ahead Markets, Elastic and Inelastic Markets– Block forwards Market - Market Structure – Power Market Types: Energy, Ancillary services and Transmission markets - Market Power - Stranded costs – Key components in power market operation

UNIT II DEMAND AND PRICE FORECASTING 9

Short Term Load Forecasting – Application of Load forecasting – Factors affecting load forecasting – Load forecasting categories - Electricity Price Forecasting –Electricity price basics – Electricity price volatility – Categorization of price forecasting – Factors considered in price Forecasting – Electricity Price simulation module- simulation example- Price forecasting module based on ANN-ANN factors in price forecasting – Performance Evaluation of price forecasting Price volatility – Price spike analysis – Probability distribution of Electricity price-Applications of price forecasting – Application of price forecast to make generation schedule – Application of probability Distribution of price to asset valuation and risk analysis – application of probability distribution to options valuation – Application of conditional probability distribution of price on Load to forward price forecasting

UNIT III PRICE BASED UNIT COMMITMENT 9

Introduction – PBUC formulation – System constraints- Unit constraints – PBUC solution – solution without emission or fuel constraints- solution with emission and fuel constraints – discussion and solution methodology – Energy purchase – Derivation of steps for updating multipliers – Optimality condition – Additional features of PBUC – Different prices among buses – Variable fuel price as a function of fuel consumption – Application of Lagrangian augmentation – Bidding strategy based on PBUC.

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UNIT IV ELECTRICITY TRADING ,GENERATION ASSET VALUATION, RISK ANALYSIS -RISK MANAGEMENT 9

Introduction – Essence of Electric Energy trading – Framework: Qualifying factors – Derivative instruments of energy trading –Application of derivatives in energy trading – Portfolio management – Energy trading Hubs-Brokers in Electricity trading – Market Risk – Hedge – Sources of Electricity market risk –Counter party risk –Risk valuation in electricity trading -- Generation Assert valuation – Asset valuation – Value at Risk(VaR)-Application of VaR to Asset valuation – VaR for Generation asset valuation- Generation capacity valuation

UNIT V TRANSMISSION CONGESTION MANAGEMENT AND PRICING 9

Introduction – Transmission cost allocation methods – Postage stamp rate method – contract path method – MW-Mile method – Unused transmission capacity method – MVA – Mile method – Counter Flow method – Distribution factor method – AC power flow method – Tracing methods - Comparison of cost allocation methods – Examples for transmission cost allocation methods – Locational Marginal Pricing (LMP) – Firm Transmission Rights(FTR) – Congestion Management – FTR Auction - Zonal congestion management – A comprehensive transmission pricing scheme – outline – prioritization of transmission dispatch – Calculation of transmission usage and congestion charges and FTR credits

TOTAL : 45 PERIODS

OUTCOMES:

- This subject gives an insight on the various electricity market models and provide knowledge about restructuring of power system.

REFERENCES

1. Mohammad Shahidehpour, Muwaffaq Almoush - Restructured Electrical Power Systems – Operation, Trading and Volatility – Marcel Dekker, Inc, NewYork
2. Mohammad Shahidehpour, Hatim Yamn, Zuyi LI – Market Operations in Electric Power Systems – Forecasting, Scheduling and Risk management – John Wiley & Sons, Inc, Publication

HV7251 PRINCIPLES OF ELECTRIC POWER TRANSMISSION **L T P C**

3 0 0 3

OBJECTIVE:

To impart knowledge on,

- types of power transmission and configurations
- various parameters and voltage gradients of transmission line conductors.
- the design requirements of EHV AC and DC lines.

UNIT I INTRODUCTION 9

Standard transmission voltages-AC and DC – different line configurations– average values of line parameters – power handling capacity and line loss – costs of transmission lines and equipment – mechanical considerations in line performance

UNIT II CALCULATION OF LINE PARAMETERS 9

Calculation of resistance, inductance and capacitance for multi-conductor lines – calculation of sequence inductances and capacitances – line parameters for different modes of propagation – effect of ground return

UNIT III VOLTAGE GRADIENTS OF CONDUCTORS 9

Charge-potential relations for multi-conductor lines – surface voltage gradient on conductors – gradient factors and their use – distribution of voltage gradient on sub conductors of bundle - voltage gradients on conductors in the presence of ground wires on towers-I^2R loss and corona loss-RIV

UNIT IV ELECTROSTATIC FIELD AND DESIGN OF EHV LINES 9

Effect of EHV line on heavy vehicles - calculation of electrostatic field of AC lines- effect of high field on humans, animals, and plants - measurement of electrostatic fields - electrostatic Induction in unenergised circuit of a D/C line - induced voltages in insulated ground wires - electromagnetic interference, Design of EHV lines

UNIT V HVDC LINES 9

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

TOTAL : 45 PERIODS

OUTCOME:

- Ability to model the transmission lines and estimate the voltage gradients and losses
- Ability to design EHV AC and DC transmission lines

REFERENCES

1. Rakosh Das Begamudre, “Extra High Voltage AC Transmission Engineering”, Second Edition, New Age International Pvt. Ltd., 2006.
2. Pritindra Chowdhari, “Electromagnetic transients in Power System”, John Wiley and Sons Inc., 2009.
3. Power Engineer’s Handbook, Revised and Enlarged 6th Edition, TNEB Engineers’ Association, October 2002.

4. Sunil S.Rao, “EHV-AC, HVDC Transmission & Distribution Engineering”, Third Edition, Khanna Publishers, 2008
5. Gas Insulated Transmission Lines (GIL) - by Hermann Koch, Oct 2011, John Wiley & Sons.
6. William H. Bailey, Deborah E. Weil and James R. Stewart . “A Review on ,”HVDC Power Transmission Environmental Issues”, Oak Ridge National Laboratory.
7. J.C Molburg, J.A. Kavicky, and K.C. Picel ,”A report on The design, Construction and operation of Long-distance High-Voltage Electricity Transmission Technologies” , Argonne (National Laboratory)

HV7073 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY **L T P C 3 0 0 3**

OBJECTIVE:

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

UNIT I INTRODUCTION 9

Definitions of EMI/EMC -Sources of EMI- Intersystems and Intrasystem- Conducted and radiated interference- Characteristics - Designing for electromagnetic compatibility (EMC)- EMC regulation- typical noise path- EMI predictions and modeling, Cross talk - Methods of eliminating interferences.

UNIT II GROUNDING AND CABLING 9

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

UNIT III BALANCING, FILTERING AND SHIELDING 9

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

UNIT IV EMI IN ELEMENTS AND CIRCUITS 9

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

UNIT V ELECTROSTATIC DISCHARGE, STANDARDS AND TESTING TECHNIQUES 9

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

TOTAL : 45 PERIODS

OUTCOME:

- Awareness towards the EMI/EMC in elements and circuits.
- Ability to design and analyze the filtering circuits for the reduction of EMI
- To design and implement the test setup

REFERENCES

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

PE7351 SPECIAL ELECTRICAL MACHINES L T P C
3 0 0 3

OBJECTIVES

- To review the fundamental concepts of permanent magnets and the operation of permanent magnet brushless DC motors.
- To introduce the concepts of permanent magnet brushless synchronous motors and synchronous reluctance motors.
- To develop the control methods and operating principles of switched reluctance motors.
- To introduce the concepts of stepper motors and its applications.
- To understand the basic concepts of other special machines.

UNIT I PERMANENT MAGNET BRUSHLESS DC MOTORS 9

Fundamentals of Permanent Magnets- Types- Principle of operation- Magnetic circuit analysis- EMF and Torque equations- Characteristics and control

UNIT II PERMANENT MAGNET SYNCHRONOUS MOTORS 9

Principle of operation – EMF and Torque equations - Phasor diagram - Power controllers – Torque speed characteristics – Digital controllers – Constructional features, operating principle and characteristics of synchronous reluctance motor.

UNIT III SWITCHED RELUCTANCE MOTORS 9

Constructional features –Principle of operation- Torque prediction–Characteristics Power controllers – Control of SRM drive- Sensorless operation of SRM – Applications.

UNIT IV STEPPER MOTORS 9

Constructional features –Principle of operation –Types – Torque predictions – Linear and Non-linear analysis – Characteristics – Drive circuits – Closed loop control –Applications.

UNIT V OTHER SPECIAL MACHINES 9

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

TOTAL: 45 PERIODS

OUTCOME:

- Ability to model and analyze power electronic systems and equipment using computational software.
- Ability to optimally design magnetics required in special machines based drive systems using FEM based software tools.
- Ability to design and conduct experiments towards research.

TEXT BOOKS:

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

REFERENCES:

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

PE7251 MICROCONTROLLER AND DSP BASED SYSTEM DESIGN **L T P C**
4 0 0 4

OBJECTIVES :

- To provide the requisite knowledge for the designing of control/triggering/closed loop circuitry employing embedded controller readily available.
- To provide with the requisite knowledge for the interfacing of the digital controllers with power electronics system for better control.
- To understand the architecture, programming methods and their special features as relevant to PE Drives
- To understand design of microcontrollers / DSP controlled systems especially for the PE interface.
- To provide knowledge about the digital implementation of conventional controllers.

UNIT I PIC 16C7X MICROCONTROLLER 12

Architecture memory organization – Addressing modes – Instruction set – Programming techniques – simple programs

UNIT II PERIPHERALS OF PIC 16C7X 12

Timers – interrupts – I/O ports – I2C bus for peripheral chip access – A/D converter– UART.

UNIT III MOTOR CONTROL SIGNAL PROCESSORS 12

Introduction- System configuration registers - Memory Addressing modes - Instruction set – Programming techniques – simple programs.

UNIT IV PERIPHERALS OF SIGNAL PROCESSORS 12

General purpose Input/Output (GPIO) Functionality- Interrupts - A/D converter-Event Managers (EVA, EVB)- PWM signal generation.

UNIT V APPLICATIONS OF PIC AND SIGNAL PROCESSORS 12

Voltage regulation of DC-DC converters- Stepper motor and DC motor control- Clarke's and parks transformation-Space vector PWM-Implementation of digital P,PI and PID controllers.

TOTAL: 60 PERIODS

OUTOME:

- Ability to develop programs for the embedded control of electrical drives.

TEXT BOOKS:

1. John B.Peatman , 'Design with PIC Microcontrollers,' Pearson Education, Asia 2004
2. Hamid A.Toliyat, Steven Campbell, 'DSP based electromechanical motion control', CRC Press

PE7073 POWER QUALITY L T P C
3 0 0 3

OBJECTIVES :

- To understand the various power quality issues.
- To understand the concept of power and power factor in single phase and three phase systems supplying nonlinear loads
- To understand the conventional compensation techniques used for power factor correction and load voltage regulation.
- To understand the active compensation techniques used for power factor correction.
- To understand the active compensation techniques used for load voltage regulation.

UNIT I INTRODUCTION 9

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

UNIT II ANALYSIS OF SINGLE PHASE AND THREE PHASE SYSTEM 9

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

UNIT III CONVENTIONAL LOAD COMPENSATION METHODS 9

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

UNIT IV LOAD COMPENSATION USING DSTATCOM 9

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

UNIT V SERIES COMPENSATION OF POWER DISTRIBUTION SYSTEM 9

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

TOTAL : 45 PERIODS

OUTCOME:

- Ability to formulate, design, simulate power supplies for generic load and for machine loads.
- Ability to conduct harmonic analysis and load tests on power supplies and drive systems.
- Ability to understand and design load compensation methods useful for mitigating power quality problems.

TEXT BOOKS

1. ArindamGhosh “Power Quality Enhancement Using Custom Power Devices”, Kluwer Academic Publishers, 2002
2. G.T.Heydt, “Electric Power Quality”, Stars in a Circle Publications, 1994(2nd edition)
3. Power Quality - R.C. Duggan
4. Power system harmonics –A.J. Arrillga
5. Power Electronic Converter Harmonics –Derek A. Paice

PE7252 MODELLING AND DESIGN OF SMPS **L T P C**
3 0 0 3

OBJECTIVE

- To provide conceptual knowledge in modern power electronic converters and its applications in electric power utility.

UNIT I STEADY-STATE CONVERTER ANALYSIS 9

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

UNIT II CONVERTER DYNAMICS 9

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

UNIT III CONTROLLER DESIGN 9

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

UNIT IV DESIGN OF MAGNETICS 9

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

UNIT V RESONANT CONVERTERS 9

Introduction- classification- basic concepts- Resonant switch- Load Resonant converters- ZVS, Clamped voltage topologies- Series and parallelResonant converters- Voltage control.

TOTAL: 45 PERIODS

OUTCOMES:

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

- Ability to optimally design magnetics required in power supplies and drive systems.
- Ability to design and conduct experiments towards research.

TEXT BOOKS:

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

REFERENCES:

1. John G.Kassakian, Martin F. Schlecht, George C. Verghese, "Principles of Power Electronics" Pearson, India, New Delhi, 2010.
2. Simon Ang and Alejandra Oliva, "Power Switching Converter" Yesdee publishers, New Delhi, 2nd edition (first Indian Reprint), 2010.
3. Philip T Krein, " Elements of Power Electronics", Oxford University Press

CO7251	NON LINEAR CONTROL	L T P C
		3 0 0 3

COURSE OBJECTIVES

- To impart knowledge on phase plane analysis of non-linear systems.
- To impart knowledge on Describing function based approach to non-linear systems.
- To educate on stability analysis of systems using Lyapunov's theory.
- To educate on stability analysis of systems using Lyapunov's theory. To introduce the concept of sliding mode control.

UNIT I PHASE PLANE ANALYSIS 9

Concepts of phase plane analysis- Phase portraits- singular points- Symmetry in phase plane portraits-Constructing Phase Portraits- Phase plane Analysis of Linear and Nonlinear Systems- Existence of Limit Cycles. simulation of phase portraits in matlab.

UNIT II DESCRIBING FUNCTION 9

Describing Function Fundamentals-Definitions-Assumptions-Computing Describing Functions-Common Nonlinearities and its Describing Functions-Nyquist Criterion and its Extension-Existence of Limit Cycles-Stability of limit Cycles. simulation of limit cycles in matlab.

UNIT III LYAPUNOV THEORY 9

Nonlinear Systems and Equilibrium Points-Concepts of Stability-Linearization and Local Stability-Lyapunov's Direct Method-Positive definite Functions and Lyapunov Functions-Equilibrium Point Theorems-Invariant Set Theorems-LTI System Analysis based on Lyapunov's Direct Method-Krasovski's Method-Variable Gradient Method-Physically – Control Design based on Lyapunov's Direct Method.

UNIT IV FEEDBACK LINEARIZATION 9

Feedback Linearization and the Canonical Form-Mathematical Tools-Input-State Linearization of SISO Systems- input-Output Linearization of SISO Systems-Generating a Linear Input-Output Relation-Normal Forms-The Zero-Dynamics-Stabilization and Tracking-Inverse Dynamics and Non-Minimum-Phase Systems-Feedback Linearization of MIMO Systems Zero-Dynamics and Control Design. Simulation of tracking problems in matlab.

UNIT V SLIDING MODE CONTROL 9

Sliding Surfaces- Continuous approximations of Switching Control laws-The Modeling/Performance Trade-Offs- MIMO Systems. simulation of sliding mode controller in matlab.

TOTAL : 45 PERIODS

COURSE OUTCOME

- Ability to represent the time-invariant systems in state space form as well as analyze,
- whether the system is stabilizable, controllable, observable and detectable.
- Ability to design state feedback controller and state observers
- Ability to classify singular points and construct phase trajectory using delta and isocline methods.
- Use the techniques such as describing function, Lyapunov Stability, Popov's Stability
- Ability to design a sliding mode controller for a MIMO process and to identify the trade off.

REFERENCES

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

PE7071 NONLINEAR DYNAMICS FOR POWER ELECTRONIC CIRCUITS L T P C
3 0 0 3

OBJECTIVES :

- To understand the non linear behavior of power electronic converters.
- To understand the techniques for investigation on non linear behavior of power electronic converters.
- To analyse the nonlinear phenomena in DC to DC converters.
- To analyse the nonlinear phenomena in AC and DC Drives.
- To introduce the control techniques for control of non linear behavior in power electronic systems.

UNIT I BASICS OF NONLINEAR DYNAMICS 9

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

UNIT II TECHNIQUES FOR INVESTIGATION OF NONLINEAR PHENOMENA 9

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

UNIT III NONLINEAR PHENOMENA IN DC-DC CONVERTERS 9

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

UNIT IV NONLINEAR PHENOMENA IN DRIVES 9

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

UNIT V CONTROL OF CHAOS 9

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

TOTAL :45 PERIODS

OUTCOME:

- Ability to understand, model and simulate chaotic behavior in power electronic systems.
- Ability to mitigate chaotic behavior noticed in power converters.

TEXT BOOKS:

1. George C. Vargheese, July 2001 Wiley – IEEE Press S Banerjee, Nonlinear Phenomena in Power Electronics, IEEE Press
2. Steven H Strogatz, Nonlinear Dynamics and Chaos, Westview Press
3. C.K.TSE Complex Behaviour of Switching Power Converters, CRC Press, 2003

PE7072 POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS **L T P C**
3 0 0 3

OBJECTIVES :

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

UNIT I INTRODUCTION 9

Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission) - Qualitative study of different renewable energy resources ocean, Biomass, Hydrogen energy systems : operating principles and characteristics of: Solar PV, Fuel cells, wind electrical systems-control strategy, operating area.

UNIT II ELECTRICAL MACHINES FOR RENEWABLE ENERGY CONVERSION 9

Review of reference theory fundamentals-principle of operation and analysis: IG, PMSG, SCIG and DFIG.

UNIT III POWER CONVERTERS 9

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

UNIT IV ANALYSIS OF WIND AND PV SYSTEMS 9

Standalone operation of fixed and variable speed wind energy conversion systems and solar system-Grid connection Issues -Grid integrated PMSG and SCIG Based WECS-Grid Integrated solar system

UNIT V HYBRID RENEWABLE ENERGY SYSTEMS 9

Need for Hybrid Systems- Range and type of Hybrid systems- Case studies of Wind-PVMaximumPower Point Tracking (MPPT).

TOTAL : 45 PERIODS

OUTCOME:

- Ability to design grid connected/standalone renewable energy system employing embedded energy storage and MPPT strategy.

TEXT BOOK

1. S.N.Bhadra, D. Kastha, & S. Banerjee “Wind Electrical Systems”, Oxford University Press, 2009

REFERENCES:

1. Rashid .M. H “power electronics Hand book”, Academic press, 2001.
2. Rai. G.D, “Non conventional energy sources”, Khanna publishes, 1993.
3. Rai. G.D,” Solar energy utilization”, Khanna publishes, 1993.
4. Gray, L. Johnson, “Wind energy system”, prentice hall linc, 1995.
5. Non-conventional Energy sources B.H.Khan Tata McGraw-hill Publishing Company, New Delhi.

CO7075 SYSTEM IDENTIFICATION AND ADAPTIVE CONTROL LT P C
3 0 0 3

COURSE OBJECTIVE

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

UNIT I MODELS FOR INDENTIFICATION 9

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

UNIT II NON-PARAMETRIC AND PARAMETRIC IDENTIFICATON 9

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

UNIT III NON-LINEAR IDENTIFICATION 9

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

UNIT IV ADAPTIVE COTROL AND ADAPTATION TECHNIQUES 9

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

UNIT V CASE STUDIES 9

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

TOTAL : 45 PERIODS

COURSE OUTCOME

- Ability to model LTI system and to analyse the Non-linear state-space model of a black box.
- Will be able to analyse frequency, spectral, correlation and transient response of a system.
- Ability to Identify the Open & closed Loop of a Non-linear system by Neural network and Fuzzy Logic controller.
- Ability to Realize different tuning parameters for adaptive control and adaptive technique.

REFERENCES

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

CO7074 ROBUST CONTROL L T P C
3 0 0 3

COURSE OBJECTIVES

- To introduce norms, random spaces and robustness measures To educate on H_2 optimal control and estimation techniques.
- To educate on Hinfinity optimal control techniques To educate on the LMI approach of Hinfinity control.
- To educate on synthesis techniques for robust controllers and illustrate through case studies.

UNIT I INTRODUCTION 9

Norms of vectors and Matrices – Norms of Systems – Calculation of operator Norms – vector Random spaces- Specification for feedback systems – Co-prime factorization and Inner functions –structured and unstructured uncertainty- robustness.

UNIT II H_2 OPTIMAL CONTROL 9

Linear Quadratic Controllers – Characterization of H_2 optimal controllers – H_2 optimal estimation-Kalman Bucy Filter – LQG Controller.

UNIT III H-INFINITY OPTIMAL CONTROL-RICCATI APPROACH 9

Formulation – Characterization of H-infinity sub-optimal controllers by means of Riccati equations – H-infinity control with full information – Hinfinity estimation

UNIT IV H-INFINITY OPTIMAL CONTROL- LMI APPROACH 9

Formulation – Characterization of H-infinity sub-optimal controllers by means of LMI Approach – Properties of H-infinity sub-optimal controllers – H-infinity synthesis with pole-placement constraints

UNIT V SYNTHESIS OF ROBUST CONTROLLERS & CASE STUDIES 9

Synthesis of Robust Controllers – Small Gain Theorem – D-K –iteration- Control of Inverted Pendulum- Control of CSTR – Control of Aircraft – Robust Control of Second-order Plant-Robust Control of Distillation Column

TOTAL : 45 PERIODS

COURSE OUTCOME

- Ability to understand the structured and unstructured uncertainty of robustness.
- Ability to design a H_2 optimal controller and to implement kalman Bucy filter .
- Ability to design a H-Infinity optimal control using Riccati and LMI Approach.
- Will be able to synthesis the Robust Controller and small gain theorem.
- Ability to implement a robust Controller for CSTR and Distillation Column.

REFERENCES

1. U. Mackenroth "Robust Control Systems: Theory and Case Studies",Springer International Edition, 2010.
2. J. B. Burl, " Linear optimal control H2 and H-infinity methods", Addison W Wesley, 1998
3. D. Xue, Y.Q. Chen, D. P. Atherton, "Linear Feedback Control Analysis and Design with MATLAB, Advances In Design and Control", Society for Industrial and Applied Mathematics, 2007.
4. I.R. Petersen, V.A. Ugrinovskii and A. V. Savkin, "Robust Control Design using H-infinity Methods", Springer, 2000.
5. M. J. Grimble, "Robust Industrial Control Systems: Optimal Design Approach for Polynomial Systems", John Wiley and Sons Ltd., Publication, 2006.

PS7073	OPTIMISATION TECHNIQUES	L T P C
		3 0 0 3

COURSE OBJECTIVES

- To introduce the different optimization problems and techniques
- To study the fundamentals of the linear and non-linear programming problem.
- To understand the concept of dynamic programming and genetic algorithm technique

UNIT I INTRODUCTION 9

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

UNIT II LINEAR PROGRAMMING (LP) 9

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

UNIT III NON LINEAR PROGRAMMING 9

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

UNIT IV DYNAMIC PROGRAMMING (DP) 9

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

UNIT V GENETIC ALGORITHM 9

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

TOTAL : 45 PERIODS

OUTCOMES

- Students will learn about different classifications of optimization problems and techniques.
- Students will attain knowledge on linear programming concepts
- Students will understand the application of non- linear programming in optimization techniques
- Students will understand the fundamental concepts of dynamic programming
- Students will have knowledge about Genetic algorithm and its application to optimization in power system.

TEXT BOOKS

1. S.S. Rao ,"Optimization – Theory and Applications", Wiley-Eastern Limited, 1984.
2. G.Luenberger," Introduction of Linear and Non-Linear Programming" , Wesley Publishing Company, 2011.

REFERENCE BOOKS:

1. Computational methods in Optimization, Polak , Academic Press,1971.
2. Optimization Theory with applications, Pierre D.A., Wiley Publications,1969.
3. Taha, H. A., Operations Research: An Introduction, Seventh Edition, Pearson Education Edition, Asia, New Delhi ,2002.

PS7074 SOLAR AND ENERGY STORAGE SYSTEM

L T P C
3 0 0 3

COURSE OBJECTIVES

- To Study about solar modules and PV system design and their applications
- To Deal with grid connected PV systems
- To Discuss about different energy storage systems

UNIT I INTRODUCTION 9

Characteristics of sunlight – semiconductors and P-N junctions –behavior of solar cells – cell properties – PV cell interconnection

UNIT II STAND ALONE PV SYSTEM 9

Solar modules – storage systems – power conditioning and regulation - protection – stand alone PV systems design – sizing

UNIT III GRID CONNECTED PV SYSTEMS 9

PV systems in buildings – design issues for central power stations – safety – Economic aspect – Efficiency and performance - International PV programs

UNIT IV ENERGY STORAGE SYSTEMS 9

Impact of intermittent generation – Battery energy storage – solar thermal energy storage – pumped hydroelectric energy storage

UNIT V APPLICATIONS 9

Water pumping – battery chargers – solar car – direct-drive applications –Space – Telecommunications.

TOTAL : 45 PERIODS

OUTCOME

- Students will develop more understanding on solar energy storage systems
- Students will develop basic knowledge on standalone PV system
- Students will understand the issues in grid connected PV systems
- Students will study about the modelling of different energy storage systems and their performances
- Students will attain more on different applications of solar energy

TEXT BOOKS

1. Eduardo Lorenzo G. Araujo, Solar electricity engineering of photovoltaic systems, Progensa,1994.
2. Stuart R.Wenham, Martin A.Green, Muriel E. Watt and Richard Corkish, Applied Photovoltaics, 2007,Earthscan, UK.

REFERENCES:

1. Frank S. Barnes & Jonah G. Levine, Large Energy storage Systems Handbook , CRC Press, 2011.
2. Solar & Wind energy Technologies – McNeils, Frenkel, Desai, Wiley Eastern, 1990
3. Solar Energy – S.P. Sukhatme, Tata McGraw Hill,1987.

PS7071 DISTRIBUTED GENERATION AND MICRO GRID **L T P C**
3 0 0 3

OBJECTIVES

- To illustrate the concept of distributed generation
- To analyze the impact of grid integration.
- To study concept of Microgrid and its configuration

UNIT I INTRODUCTION 9

Conventional power generation: advantages and disadvantages, Energy crises, Non-conventional energy (NCE) resources: review of Solar PV, Wind Energy systems, Fuel Cells, micro-turbines, biomass, and tidal sources.

UNIT II DISTRIBUTED GENERATIONS (DG) 9

Concept of distributed generations, topologies, selection of sources, regulatory standards/ framework, Standards for interconnecting Distributed resources to electric power systems: IEEE 1547. DG installation classes, security issues in DG implementations. Energy storage elements: Batteries, ultra-capacitors, flywheels. Captive power plants

UNIT III IMPACT OF GRID INTEGRATION 9

Requirements for grid interconnection, limits on operational parameters,: voltage, frequency, THD, response to grid abnormal operating conditions, islanding issues. Impact of grid integration with NCE sources on existing power system: reliability, stability and power quality issues.

UNIT IV BASICS OF A MICROGRID 9

Concept and definition of microgrid, microgrid drivers and benefits, review of sources of microgrids, typical structure and configuration of a microgrid, AC and DC microgrids, Power Electronics interfaces in DC and AC microgrids,

UNIT V CONTROL AND OPERATION OF MICROGRID 9

Modes of operation and control of microgrid: grid connected and islanded mode, Active and reactive power control, protection issues, anti-islanding schemes: passive, active and communication based techniques, microgrid communication infrastructure, Power quality issues in microgrids, regulatory standards, Microgrid economics, Introduction to smart microgrids.

TOTAL : 45 PERIODS

OUTCOMES

- Students will attain knowledge on the various schemes of conventional and non-conventional power generation.
- Students will have knowledge on the topologies and energy sources of distributed generation.
- Students will learn about the requirements for grid interconnection and its impact with NCE sources
- Students will understand the fundamental concept of Microgrid.

REFERENCES

1. "Voltage Source Converters in Power Systems: modelling, Control and Applications", Amirnaser Yezdani, and Reza Iravani, IEEE John Wiley Publications.
2. "Power Switching Converters: Medium and High Power", DorinNeacsu, CRC Press, Taylor & Francis, 2006.
3. "Solar Photo Voltaics", Chetan Singh Solanki, PHI learning Pvt. Ltd., New Delhi,2009
4. "Wind Energy Explained, theory design and applications," J.F. Manwell, J.G. McGowan Wiley publication
5. "Biomass Regenerable Energy", D. D. Hall and R. P. Grover, John Wiley, New York, 1987.
6. "Renewable Energy Resources" John Twidell and Tony Weir, Tyalor and Francis Publications, Second edition.

PW7351 ENERGY MANAGEMENT AND AUDITING **L T P C**
3 0 0 3

COURSE OBJECTIVES

- To study the concepts behind economic analysis and Load management.
- To emphasize the energy management on various electrical equipments and metering.
- To illustrate the concept of lighting systems and cogeneration.

UNIT I INTRODUCTION 9

Need for energy management - energy basics- designing and starting an energy management program – energy accounting -energy monitoring, targeting and reporting-energy audit process.

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

UNIT III ENERGY MANAGEMENT FOR MOTORS, SYSTEMS, AND ELECTRICAL EQUIPMENT 9

Systems and equipment- Electric motors-Transformers and reactors-Capacitors and synchronous machines

UNIT IV METERING FOR ENERGY MANAGEMENT 9

Relationships between parameters-Units of measure-Typical cost factors- Utility meters - Timing of meter disc for kilowatt measurement - Demand meters - Paralleling of current transformers - Instrument transformer burdens-Multitasking solid-state meters - Metering location vs. requirements- Metering techniques and practical examples

UNIT V LIGHTING SYSTEMS & COGENERATION 9

Concept of lighting systems - The task and the working space -Light sources - Ballasts - Luminaries - Lighting controls-Optimizing lighting energy - Power factor and effect of harmonics on power quality - Cost analysis techniques-Lighting and energy standards Cogeneration: Forms of cogeneration - feasibility of cogeneration- Electrical interconnection.

TOTAL : 45 PERIODS

OUTCOME

- Students will develop the ability to learn about the need for energy management and auditing process
- Learners will learn about basic concepts of economic analysis and load management.
- Students will understand the energy management on various electrical equipments.
- Students will have knowledge on the concepts of metering and factors influencing cost function
- Students will be able to learn about the concept of lighting systems, light sources and various forms of cogeneration

TEXT BOOKS

1. Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, Guide to Energy Management, Fifth Edition, The Fairmont Press, Inc., 2006
2. Eastop T.D & Croft D.R, Energy Efficiency for Engineers and Technologists,. Logman Scientific & Technical, ISBN-0-582-03184, 1990.

REFERENCES

1. Reay D.A, Industrial Energy Conservation, 1st edition, Pergamon Press, 1977.
2. IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities, IEEE, 196.
3. Amit K. Tyagi, Handbook on Energy Audits and Management, TERI, 2003.

PS7072 HIGH VOLTAGE DIRECT CURRENT TRANSMISSION

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

- To impart knowledge on operation, modelling and control of HVDC link.
- To perform steady state analysis of AC/DC system.
- To expose various HVDC simulators.

UNIT I DC POWER TRANSMISSION TECHNOLOGY 6

Introduction - Comparison of AC and DC transmission – Application of DC transmission – Description of DC transmission system - Planning for HVDC transmission – Modern trends in DC transmission – DC breakers – Cables, VSC based HVDC.

UNIT II ANALYSIS OF HVDC CONVERTERS AND HVDC SYSTEM CONTROL **12**

Pulse number, choice of converter configuration – Simplified analysis of Graetz circuit - Converter bridge characteristics – characteristics of a twelve pulse converter- detailed analysis of converters. General principles of DC link control – Converter control characteristics – System control hierarchy - Firing angle control – Current and extinction angle control – Generation of harmonics and filtering - power control – Higher level controllers.

UNIT III MULTITERMINAL DC SYSTEMS **9**

Introduction – Potential applications of MTDC systems - Types of MTDC systems - Control and protection of MTDC systems - Study of MTDC systems.

UNIT IV POWER FLOW ANALYSIS IN AC/DC SYSTEMS **9**

Per unit system for DC Quantities - Modelling of DC links - Solution of DC load flow - Solution of AC-DC power flow – Unified, Sequential and Substitution of power injection method.

UNIT V SIMULATION OF HVDC SYSTEMS **9**

Introduction – DC LINK Modelling , Converter modelling and State Space Analysis , Philosophy and tools – HVDC system simulation, Online and Offline simulators –– Dynamic interactions between DC and AC systems.

TOTAL : 45 PERIODS

OUTCOME

- Students will develop understanding on DC power transmission technologies,
- Students will study about HVDC converters and HVDC system control,
- Students will develop understanding on multi-terminal DC system,
- Students will attain knowledge on AC/DC power flow analysis,
- Students will study about modeling of HVDC systems and HVDC system simulation techniques.

TEXT BOOKS

1. P. Kundur, “Power System Stability and Control”, McGraw-Hill, 1993
2. K.R.Padiyar, , “HVDC Power Transmission Systems”, New Age International (P) Ltd., New Delhi, 2002.

REFERENCES

1. J.Arrillaga, , “High Voltage Direct Current Transmission”, Peter Pregrinus, London, 1983.
2. Erich Uhlmann, “ Power Transmission by Direct Current”, BS Publications, 2004.
3. V.K.Sood,HVDC and FACTS controllers – Applications of Static Converters in Power System, APRIL 2004 , Kluwer Academic Publishers.

PS7075 WIND ENERGY CONVERSION SYSTEM LT P C
3 0 0 3

COURSE OBJECTIVES

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

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

UNIT II WIND TURBINES 9
HAWT-VAWT-Power developed-Thrust-Efficiency-Rotor selection-Rotor design considerations-Tip speed ratio-No. of Blades-Blade profile-Power Regulation-yaw control-Pitch angle control-stall control-Schemes for maximum power extraction.

UNIT III FIXED SPEED SYSTEMS 9
Generating Systems- Constant speed constant frequency systems -Choice of Generators-Deciding factors-Synchronous Generator-Squirrel Cage Induction Generator- Model of Wind Speed- Model wind turbine rotor - Drive Train model- Generator model for Steady state and Transient stability analysis.

UNIT IV VARIABLE SPEED SYSTEMS 9
Need of variable speed systems-Power-wind speed characteristics-Variable speed constant frequency systems synchronous generator- DFIG- PMSG -Variable speed generators modelling - Variable speed variable frequency schemes.

UNIT V GRID CONNECTED SYSTEMS 9
Wind interconnection requirements, low-voltage ride through (LVRT), ramp rate limitations, and supply of ancillary services for frequency and voltage control, current practices and industry trends wind interconnection impact on steady-state and dynamic performance of the power system including modelling issue.

TOTAL: 45 PERIODS

OUTCOMES

- Students will attain knowledge on the basic concepts of Wind energy conversion system.
- Students will have the knowledge of the mathematical modelling and control of the Wind turbine
- Students will develop more understanding on the design of Fixed speed system
- Students will study about the need of Variable speed system and its modelling.
- Students will learn about Grid integration issues and current practices of wind interconnections with power system.

TEXT BOOKS

1. L.L.Freris "Wind Energy conversion Systems", Prentice Hall, 1990
2. S.N.Bhadra, D.Kastha,S.Banerjee,"Wind Electrical Sytems",Oxford University Press,2010.

REFERENCES

2. Ion Boldea, “Variable speed generators”, Taylor & Francis group, 2006.
3. E.W.Golding “The generation of Electricity by wind power”, Redwood burn Ltd., Trowbridge,1976.
4. N. Jenkins,” Wind Energy Technology” John Wiley & Sons,1997
5. S.Heir “Grid Integration of WECS”, Wiley 1998.

PS7001 POWER SYSTEM PLANNING AND RELIABILITY **L T P C**
3 0 0 3

COURSE OBJECTIVES

- To introduces the objectives of Load forecasting.
- To study the fundamentals of Generation system, transmission system and
- Distribution system reliability analysis
- To illustrate the basic concepts of Expansion planning

UNIT I LOAD FORECASTING 9

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

UNIT II GENERATION SYSTEM RELIABILITY ANALYSI 9

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

UNIT III TRANSMISSION SYSTEM RELIABILITY ANALYSIS 9

Deterministic contingency analysis-probabilistic load flow-Fuzzy load flow probabilistic transmission system reliability analysis-Determination of reliability indices like LOLP and expected value of demand not served.

UNIT IV EXPANSION PLANNING 9

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

UNIT V DISTRIBUTION SYSTEM PLANNING OVERVIEW 9

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

TOTAL: 45 PERIODS

OUTCOMES:

- Students will develop the ability to learn about load forecasting.
- Students will learn about reliability analysis of ISO and interconnected systems.
- Students will understand the concepts ot Contingency analysis and Probabilistic Load flow analysis

- Students will be able to understand the concepts of Expansion planning
- Students will have knowledge on the fundamental concepts of the Distribution system planning

TEXT BOOK:

1. Reliability Evaluation of Power System - Roy Billinton & Ronald N. Allan, Springer Publication
2. Power System Planning - R.L. Sullivan, Tata McGraw Hill Publishing Company Ltd.

REFERENCES:

1. Modern Power System Planning – X. Wang & J.R. McDonald, McGraw Hill Book Company
2. Electrical Power Distribution Engineering - T. Gönen, McGraw Hill Book Company
3. Generation of Electrical Energy – B.R. Gupta, S. Chand Publications

ET7351 DISTRIBUTED EMBEDDED COMPUTING **L T P C**
3 0 0 3

COURSE OBJECTIVES

- To expose the students to the fundamentals of Network communication technologies.
- To teach the fundamentals of Internet
- To study on Java based Networking
- To introduce network routing Agents
- To involve Discussions/ Practice/Exercise onto revising & familiarizing the concepts acquired over the 5 Units of the subject for improved employability skills

UNIT I INTERNET INFRASTRUCTURE 9

Broad Band Transmission facilities –OpenInterconnection standards –Local Area Networks – Wide Area Networks –Network management – Network Security – Cluster computers.

UNIT II INTERNET CONCEPTS 9

Capabilities and limitations of the internet -– Interfacing Internet server applications to corporate databases HTML and XML Web page design through programming and the use of active components.

UNIT III EMBEDDED JAVA 9

Introduction to Embedded Java and J2ME - embedded java concepts -IO streaming – Object serialization – Networking – Threading – RMI – multicasting – distributed databases –– Smart Card basics – Java card technology overview – Java card objects – Java card applets – Web Technology for Embedded Systems.

UNIT IV EMBEDDED AGENT 9

Introduction to the embedded agents – Embedded agent design criteria – Behaviour based, Functionality based embedded agents – Agent co-ordination mechanisms and benchmarks embedded-agent. Case study: Mobile robots.

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UNIT V EMBEDDED COMPUTING ARCHITECTURE 9

Synthesis of the information technologies of distributed embedded systems – analog/digital co-design – optimizing functional distribution in complex system design – validation and fast prototyping of multiprocessor system-on-chip – a new dynamic scheduling algorithm for real-time multiprocessor systems.

Note :Discussions/Practice on Workbench : Program Development and practice in exercises with XML/HTML/Java Programming Environments.

TOTAL : 45 PERIODS

COURSE OUTCOME:

- The learning process delivers insight into involving JAVA concepts& internet based communication to establish decentralized control mechanism of system
- Improved Employability and entrepreneurship capacity due to knowledge up gradation on recent trends in embedded systems design.

REFERENCES:

1. Dietel & Dietel, "JAVA how to program", Prentice Hall 1999.
2. Sape Mullender, "Distributed Systems", Addison-Wesley, 1993.
3. George Coulouris and Jean Dollimore, "Distributed Systems – concepts and design",Addison –Wesley 1988.
4. "Architecture and Design of Distributed Embedded Systems", edited by Bernd Kleinjohann C-lab, Universitat Paderborn, Germany, Kluwer AcademicPub, Boston, April 2001, 248 pp.
5. Wigglesworth,"Java Programming Advanced Topics,Cengage,2010
6. Mclaughlin,"Java & XML,O'reilly,2006.

ET7074 MEMS TECHNOLOGY L T P C
3 0 0 3

Course objectives

- To teach the students properties of materials ,microstructure and fabrication methods.
- To teach the design and modeling of Electrostatic sensors and actuators.
- To teach the characterizing thermal sensors and actuators through design and modeling
- To teach the fundamentals of piezoelectric sensors and actuators through exposure to different MEMS and NEMS devices
- To involve Discussions/ Practice/Exercise onto revising & familiarizing the concepts acquired over the 5 Units of the subject for improved employability skills

UNIT I MICRO-FABRICATION, MATERIALS AND ELECTRO-MECHANICAL CONEPTS 9

Overview of micro fabrication – Silicon and other material based fabrication processes – Concepts:

Conductivity of semiconductors-Crystal planes and orientation-stress and strain-flexural beam bending analysis-torsional deflections-Intrinsic stress- resonant frequency and quality factor.

UNIT II ELECTROSTATIC SENSORS AND ACTUATION 9

Principle, material, design and fabrication of parallel plate capacitors as electrostatic sensors and actuators-Applications

UNIT III THERMAL SENSING AND ACTUATION 9

Principle, material, design and fabrication of thermal couples, thermal bimorph sensors, thermal resistor sensors-Applications.

UNIT IV PIEZOELECTRIC SENSING AND ACTUATION 9

Piezoelectric effect-cantilever piezo electric actuator model-properties of piezoelectric materials-Applications.

UNIT V CASE STUDIES 9

Piezoresistive sensors, Magnetic actuation, Micro fluidics applications, Medical applications, Optical MEMS.-NEMS Devices Note :Discussions/Exercise/Practice on Workbench : on the basics /device model design aspects of thermal/peizo/resistive sensors etc.

TOTAL : 45 PERIODS

COURSE OUTCOME:

- The learning process delivers insight onto design of micro sensors, embedded sensors & actuators in power aware systems like grid
- Improved Employability and entrepreneurship capacity due to knowledge up gradation on recent trends in embedded systems design.

REFERENCES

1. Chang Liu, “Foundations of MEMS”, Pearson International Edition, 2006.
2. Marc Madou , “Fundamentals of microfabrication”,CRC Press, 1997.
3. Boston , “Micromachined Transducers Sourcebook”,WCB McGraw Hill, 1998.
4. M.H.Bao “Micromechanical transducers :Pressure sensors, accelerometers and gyroscopes”, Elsevier, Newyork, 2000.

HV7072 DESIGN OF SUBSTATIONS L T P C
3 0 0 3

OBJECTIVE:

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

UNIT I INTRODUCTION TO AIS AND GIS 9

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

UNIT II MAJOR EQUIPMENT AND LAYOUT OF AIS AND GIS 9

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

UNIT III INSULATION COORDINATION OF AIS AND GIS 9

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

UNIT IV GROUNDING AND SHIELDING 9

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

UNIT V FAST TRANSIENTS PHENOMENON IN AIS AND GIS 9

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

TOTAL : 45 PERIODS

OUTCOME:

- Awareness towards substation equipment and their arrangements.
- Ability to design the substation for present requirement with proper insulation coordination and protection against fast transients.

REFERENCES

1. Andrew R. Hileman, "Insulation coordination for power systems", Taylor and Francis, 1999.
2. M.S. Naidu, "Gas Insulation Substations", I.K. International Publishing House Private Limited, 2008.
3. Klaus Ragallar, "Surges in high voltage networks" Plenum Press,New York, 1980.
4. "Power Engineer's handbook", TNEB Association.
5. Pritindra Chowdhuri, "Electromagnetic transients in power systems", PHI Learning Private Limited, New Delhi, Second edition, 2004.
6. "Design guide for rural substation", United States Department of Agriculture, RUS Bulletin, 1724E-300, June 2001.
7. AIEE Committee Report, "Substation One-line Diagrams," AIEE Trans. on Power Apparatus and Systems, August 1953
8. Hermann Koch , "Gas Insulated Substations", Wiley-IEEE Press,2014

PW7201 GRID INTEGRATION OF RENEWABLE ENERGY SOURCES **L T P C**
3 0 0 3

COURSE OBJECTIVE:

- To study about the integration of various renewable energy sources into the grid
- To analyze the grid integration issues of renewable generation and dynamic performance of the network

UNIT I GRID INTEGRATION 9

Introduction to renewable energy grid integration - Concept of mini/micro grids and Smart grids - Different types of grid interfaces - Issues related to grid integration of small and large scale of synchronous generator based - induction generator based and converter based sources together - Network voltage management (discusses the issue of voltage levels) - Power qualitymanagement (voltage dips, harmonics, flickers and reactive power control) - Frequency management - Influence of WECS on system transient response - Interconnection standards and grid code requirements for integration.

UNIT II NETWORK INTEGRATION OF WIND POWER 9

Introduction - Wind farm starting - Network voltage management - Thermal/active power management - Network power quality management - Transient system performance - Fault level issues – Protection.

UNIT III INFLUENCE OF WIND FARMS ON NETWORK DYNAMIC PERFORMANCE 9

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

UNIT IV POWER SYSTEMS STABILIZERS AND NETWORK DAMPING CAPABILITY OF WIND FARMS 9

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

UNIT V STAND ALONE AND GRID CONNECTED PV SYSTEM 9

Solar modules – storage systems – power conditioning and regulation - protection – standalone PV systems design – sizing - PV systems in buildings – design issues for central power stations – safety – Economic aspect – Efficiency and performance - International PV programs

TOTAL: 45 PERIODS

OUTCOME:

- This course provides a brief knowledge about integration of various renewable energy sources into the grid and its issues.

TEXT BOOKS:

1. Eduardo Lorenzo G. Araujo, Solar electricity engineering of photovoltaic systems,Progensa,1994.
2. Stuart R.Wenham, Martin A.Green, Muriel E. Watt and Richard Corkish, Applied Photovoltaics, 2007,Earthscan, UK.

REFERENCES

1. Olimpo Anaya-Lara, Nick Jenkins, Janaka Ekanayake, Phill Cartwright and Mike Hughes :" WIND ENERGY GENERATION Modelling and Control" A John Wiley and Sons, Ltd., Publication (2009)
2. Brendan Fox, Damian Flynn and Leslie Bryans: "Wind Power Integration Connection and system operational aspects" Published by The Institution of Engineering and Technology, London, United Kingdom (2007).
3. Frank S. Barnes & Jonah G. Levine, Large Energy storage Systems Handbook , CRC Press, 2011.
4. Solar & Wind energy Technologies – McNeils, Frenkel, Desai, Wiley Eastern, 1990
5. Solar Energy – S.P. Sukhatme, Tata McGraw Hill,1987.

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