UNIVERSITY DEPARTMENTS

ANNA UNIVERSITY CHENNAI : : CHENNAI 600 025

REGULATIONS - 2009

CURRICULUM I TO IV SEMESTERS (FULL TIME)

M.E. POWER SYSTEMS ENGINEERING

SEMESTER I

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	MA9122	Applied Mathematics for Electrical Engineers	3	1	0	4
2	PS9111	Power System Analysis	3	1	0	4
3	PS9112	Power System Operation and Control	3	0	0	3
4	PS9113	Electrical Transients in Power Systems	3	0	0	3
5	CO9112	System Theory	3	0	0	3
6	E1	Elective I	3	0	0	3
PRACTICAL						
7	PS9114	Power System Simulation Laboratory I	0	0	3	2
		TOTAL	**15**	**2**	**3**	**22**

SEMESTER II

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	PS9121	Power System Protection	3	0	0	3
2	PS9122	Power System Dynamics	3	0	0	3
3	PS9123	Flexible AC Transmission systems	3	0	0	3
4	PS9124	Restructured Power Systems	3	0	0	3
5	E2	Elective II	3	0	0	3
6	E3	Elective III	3	0	0	3
PRACTICAL						
7	PS9125	Power System Simulation Laboratory II	0	0	3	2
		TOTAL	**18**	**0**	**3**	**20**

SEMESTER III

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	E4	Elective IV	3	0	0	3
2	E5	Elective V	3	0	0	3
3	E6	Elective V	3	0	0	3
PRACTICAL						

4	PS9131	Project Work (Phase –I)	0	0	12	6
		TOTAL	**9**	**0**	**12**	**15**

SEMESTER IV

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
PRACTICAL						
1	PS9141	Project work (Phase –II)	0	0	24	12
		TOTAL	**0**	**0**	**24**	**12**

TOTAL CREDITS TO BE EARNED FOR THE AWARD THE DEGREE = 69

ELECTIVES FOR POWER SYSTEM ENGINEERING

SEMESTER I

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	HV9111	Electro Magnetic Field Computation and Modelling	3	1	0	4
2	PE9111	Analysis of Electrical Machines	3	0	0	3
3	PE9113	Analysis of Inverters	3	0	0	3

SEMESTER II

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
1	HV9124	EHV Power Transmission	3	0	0	3
2	EB9123	Special Electrical Machines	3	0	0	3
3	PE9152	Power Quality	3	0	0	3
4	PS9151	Power System Planning and Reliability	3	0	0	3
5	ET9159	Advanced Digital Signal Processing	3	0	0	3
6	CO9113	Control System Design	3	1	0	4

SEMESTER III

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
1	CO9155	Optimal Control and Filtering	3	0	0	3
2	PS9152	Advanced Power System Dynamics	3	0	0	3
3	CO9157	System Identification and Adaptive Control	3	0	0	3
4	PS9153	Industrial Power System Analysis and Design	3	0	0	3
5	PS9154	High Voltage Direct Current Transmission	3	0	0	3
6	PS9155	Wind Energy Conversion Systems	3	0	0	3
7	CO9151	Soft Computing Techniques	3	0	0	3
8	PE9154	Power Electronics for Renewable Energy Systems	3	0	0	3
9	EB9152	Applications of MEMS Technology	3	0	0	3

UNIVERSITY DEPARTMENTS

ANNA UNIVERSITY CHENNAI : : CHENNAI 600 025

REGULATIONS - 2009

CURRICULUM I TO VI SEMESTERS (PART TIME)

M.E. POWER SYSTEMS ENGINEERING

SEMESTER I

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	MA9122	Applied Mathematics for Electrical Engineers	3	1	0	4
2	PS9112	Power System Operation and Control	3	0	0	3
3	PS9111	Power System Analysis	3	1	0	4
		TOTAL	**9**	**2**	**0**	**11**

SEMESTER II

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	PS9121	Power System Protection	3	0	0	3
2	PS9122	Power System Dynamics	3	0	0	3
3	PS9124	Restructured Power Systems	3	0	0	3
		TOTAL	**9**	**0**	**0**	**9**

SEMESTER III

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	PS9113	Electrical Transients in Power Systems	3	0	0	3
2	CO9112	Systems Theory	3	0	0	3
3	E1	Elective I	3	0	0	3
PRACTICAL						
4	PS9114	Power System Simulation Laboratory I	0	0	3	2
		TOTAL	**9**	**0**	**3**	**11**

SEMESTER IV

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	PS9123	Flexible AC Transmission systems	3	0	0	3
2	E2	Elective II	3	0	0	3
3	E3	Elective III	3	0	0	3
PRACTICAL						
4	PS9125	Power System Simulation Laboratory II	0	0	3	2

	TOTAL	**9**	**0**	**3**	**11**

SEMESTER V

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	E4	Elective IV	3	0	0	3
2	E5	Elective V	3	0	0	3
3	E6	Elective VI	3	0	0	3
PRACTICAL						
4	PS9131	Project Work (Phase –I)	0	0	12	6
		TOTAL	**9**	**0**	**12**	**15**

SEMESTER VI

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
PRACTICAL						
1	PS9141	Project work (Phase –II)	0	0	24	12
		TOTAL	**0**	**0**	**24**	**12**

TOTAL CREDITS TO BE EARNED FOR THE AWARD THE DEGREE = 69

ELECTIVES FOR POWER SYSTEM ENGINEERING

SEMESTER III

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	HV9111	Electro Magnetic Field Computation and Modelling	3	1	0	4
2	PE9111	Analysis of Electrical Machines	3	0	0	3
3	PE9113	Analysis of Inverters	3	0	0	3

SEMESTER IV

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
4	HV9124	EHV Power Transmission	3	0	0	3
5	EB9123	Special Electrical Machines	3	0	0	3
6	PE9152	Power Quality	3	0	0	3
7	PS9121	Power System Planning and Reliability	3	0	0	3
8	ET9159	Advanced Digital Signal Processing	3	0	0	3
9	CO9113	Control System Design	3	0	0	3

SEMESTER V

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
10	CO 9155	Optimal Control and Filtering	3	0	0	3
11	PS9152	Advanced Power System Dynamics	3	0	0	3
12	CO9157	System Identification and Adaptive Control	3	0	0	3
13	PS9153	Industrial Power System Analysis and Design	3	0	0	3
14	PS9154	High Voltage Direct Current Transmission	3	0	0	3
15	PS9155	Wind Energy Conversion Systems	3	0	0	3
16	CO 9151	Soft Computing Techniques	3	0	0	3
17	PE9154	Power Electronics for Renewable Energy Systems	3	0	0	3
18	EB9152	Applications of MEMS Technology	3	0	0	3

MA 9122 APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS L T P C
3 1 0 4

1. ADVANCED MATRIX THEORY: 9
Eigen-values using QR transformations – Generalized eigen vectors – Canonical forms – Singular value decomposition and applications – Pseudo inverse – Least square approximations.

2. LINEAR PROGRAMMING 9
Formulation – Graphical Solution – Simplex Method – Two Phase Method – Transportation and Assignment Problems.

3. ONE DIMENSIONAL RANDOM VARIABLES **9**

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.

4. QUEUEING MODELS **9**

Poisson Process – Markovian queues – Single and Multi Serve r Models – Little's formula – Machine Interference Model – Steady State analysis – Self Service queue.

5. COMPUTATIONAL METHODS IN ENGINEERING **9**

Boundary value problems for ODE – Finite difference methods – Numerical solution of PDE – Solution of Laplace and Poisson equations – Liebmann's iteration process – Solution of heat conduction equation by Schmidt explicit formula and Crank-Nicolson implicit scheme – Solution of wave equation.

L= 45 T=15 TOTAL = 60

REFERENCES:

1. Bronson, R., Matrix Operation, Schaum's outline series, McGraw Hill, New York, (1989).
2. Taha, H. A., Operations Research: An Introduction, Seventh Edition, Pearson Education Edition, Asia, New Delhi (2002).
3. R. E. Walpole, R. H. Myers, S. L. Myers, and K. Ye, Probability and Statistics for Engineers & Scientists, Asia, 8th Edition, (2007).
4. Donald Gross and Carl M. Harris, Fundamentals of Queueing theory, 2nd edition, John Wiley and Sons, New York (1985).
5. Grewal, B.S., Numerical methods in Engineering and Science, 7th edition, Khanna Publishers, 200

PS 9111 **POWER SYSTEM ANALYSIS** **L T P C**
3 1 0 4

1. SOLUTION TECHNIQUE **9**

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

2. POWER FLOW ANALYSIS **9**

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; Net Interchange power control in Multi-area power flow analysis: ATC, Assessment of Available

Transfer Capability (ATC) using Repeated Power Flow method; Continuation Power Flow method.

3. OPTIMAL POWER FLOW 9

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

4. SHORT CIRCUIT ANALYSIS 9

Fault calculations using sequence networks for different types of faults. Bus impedance matrix (Z_{BUS}) construction using Building Algorithm for lines with mutual coupling; Simple numerical problems. 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 domain using Thevenin's equivalent and Z_{BUS} matrix for different faults.

5. TRANSIENT STABILITY ANALYSIS 9

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

L= 45 T=15 Total = 60

REFERENCES:

1. G W Stagg , A.H El. Abiad "Computer Methods in Power System Analysis", McGraw Hill, 1968.
2. P.Kundur, "Power System Stability and Control", McGraw Hill, 1994.
3. A.J.Wood and B.F.Wollenberg, "Power Generation Operation and Control", John Wiley and sons, New York, 1996.
4. 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.
5. 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.

PS 9112 POWER SYSTEM OPERATION AND CONTROL

L T P C
3 0 0 3

1. LOAD FORECASTING 9

Introduction – Estimation of Average and trend terms – Estimation of periodic components – Estimation of Stochastic components : Time series approach – Auto- Regressive Model, Auto-Regressive Moving – Average Models – Kalman Filtering Approach – On-line techniques for non stationary load prediction.

2. UNIT COMMITMENT 9

Constraints in unit commitment – Spinning reserve – Thermal unit constraints – Other constraints – Solution using Priority List method, Dynamic programming method - Forward DP approach Lagrangian relaxation method – adjusting λ.

3. GENERATION SCHEDULING 9

The Economic dispatch problem – Thermal system dispatching with network losses considered – The Lambda – iteration method – Gradient method of economic dispatch – Economic dispatch with Piecewise Linear cost functions – Transmission system effects – A two generator system – coordination equations – Incremental losses and penalty factors-Hydro Thermal Scheduling using DP.

4. CONTROL OF POWER SYSTEMS 9

Review of AGC and reactive power control -System operating states by security control functions – Monitoring, evaluation of system state by contingency analysis – Corrective controls (Preventive, emergency and restorative) - Energy control center – SCADA system – Functions – monitoring , Data acquisition and controls – EMS system.

5. STATE ESTIMATION 9

Maximum likelihood Weighted Least Squares Estimation: - Concepts - Matrix formulation - Example for Weighted Least Squares state estimation ; State estimation of an AC network: development of method – Typical results of state estimation on an AC network – State Estimation by Orthogonal Decomposition algorithm – Introduction to Advanced topics : Detection and Identification of Bad Measurements , Estimation of Quantities Not Being Measured , Network Observability and Pseudo – measurements – Application of Power Systems State Estimation .

TOTAL : 45 PERIODS

REFERENCES

1. O.I.Elgerd, "Electric Energy System Theory - an Introduction", - Tata McGraw Hill, New Delhi – 2002.
2. P.Kundur ; "Power System Stability and Control", EPRI Publications, California , 1994.
3. Allen J.Wood and Bruce.F.Wollenberg, "Power Generation Operation and Control', John Wiley & Sons , New York, 1996.
4. A.K.Mahalanabis, D.P.Kothari. and S.I.Ahson., "Computer Aided Power System Analysis and Control", Tata McGraw Hill publishing Ltd , 1984.

PS 9113 ELECTRICAL TRANSIENTS IN POWER SYSTEMS

L T P C
3 0 0 3

1. TRAVELLING WAVES ON TRANSMISSION LINE 9

Lumped and Distributed Parameters – Wave Equation – Reflection, Refraction, Behaviour of Travelling waves at the line terminations – Lattice Diagrams – Attenuation and Distortion – Multi-conductor system and Velocity wave.

2. COMPUTATION OF POWER SYSTEM TRANSIENTS 9

Principle of digital computation – Matrix method of solution, Modal analysis, Z transforms, Computation using EMTP – Simulation of switches and non-linear elements.

3. LIGHTNING, SWITCHING AND TEMPORARY OVERVOLTAGES 9

Lightning: Physical phenomena of lightning – Interaction between lightning and power system – Factors contributing to line design – Switching: Short line or kilometric fault – Energizing transients - closing and re-closing of lines - line dropping, load rejection - Voltage induced by fault – Very Fast Transient Overvoltage (VFTO)

4. BEHAVIOUR OF WINDING UNDER TRANSIENT CONDITION 9
Initial and Final voltage distribution - Winding oscillation - traveling wave solution - Behaviour of the transformer core under surge condition – Rotating machine – Surge in generator and motor

5. INSULATION CO-ORDINATION 9
Principle of insulation co-ordination in Air Insulated substation (AIS) and Gas Insulated Substation (GIS), insulation level, statistical approach, co-ordination between insulation and protection level –overvoltage protective devices – lightning arresters, substation earthing.

TOTAL : 45 PERIODS

REFERENCES

1. Pritindra Chowdhari, "Electromagnetic transients in Power System", John Wiley and Sons Inc., 1996.
2. Allan Greenwood, "Electrical Transients in Power System", Wiley & Sons Inc. New York, 1991.
3. Klaus Ragaller, "Surges in High Voltage Networks", Plenum Press, New York, 1980.
4. Rakosh Das Begamudre, "Extra High Voltage AC Transmission Engineering", (Second edition) Newage International (P) Ltd., New Delhi, 1990.
5. Naidu M S and Kamaraju V, "High Voltage Engineering", Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2004.
6. IEEE Guide for safety in AC substation grounding IEEE Standard 80-2000.
7. Working Group 33/13-09 (1988), 'Very fast transient phenomena associated with Gas Insulated System', CIGRE, 33-13, pp. 1-20.

CO 9112 SYSTEM THEORY **L T P C**
3 0 0 3

1**. STATE VARIABLE REPRESENTATION 9**
Introduction-Concept of State-State equation for Dynamic Systems-Time invariance and linearity-Nonuniqueness of state model-State Diagrams-Physical System and State Assignment.

2. **SOLUTION OF STATE EQUATION 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.

3. 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.

4. STABILITY **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.

5. 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

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.

PS 9114 POWER SYSTEM SIMULATION LABORATORY-I

L T P C
0 0 3 2

LIST OF EXPERIMENTS

1. Power flow analysis by Newton-Raphson method
2. Power flow analysis by Fast decoupled method
3. Transient stability analysis of single machine-infinite bus system using classical machine model

4. Contingency analysis: Generator shift factors and line outage distribution factors
5. Economic dispatch using lambda-iteration method
6. Unit commitment: Priority-list schemes and dynamic programming
7. Analysis of switching surge using EMTP : Energisation of a long distributed-parameter line
8. Analysis of switching surge using EMTP : Computation of transient recovery voltage

P = 45 Total= 45

PS 9121 POWER SYSTEM PROTECTION L T P C
3 0 0 3

1. EQUIPMENT PROTECTION 9

Types of transformers – Phasor diagram for a three – Phase transformer-Equivalent circuit of transformer – Types of faults in transformers- Over – current protection Percentage Differential Protection of Transformers - Inrush phenomenon-High resistance Ground Faults in Transformers - Inter-turn faults in transformers - Incipient faults in transformers - Phenomenon of over-fluxing in transformers - Transformer protection application chart .Electrical circuit of the generator –Various faults and abnormal operating conditions-rotor fault –Abnormal operating conditions; numerical examples for typical transformer and generator protection schemes

2. OVER CURRENT PROTECTION 9

Time – Current characteristics-Current setting – Time setting-Over current protective schemes - Reverse power or directional relay - Protection of parallel feeders - Protection of ring feeders - 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 example for a radial feeder

3. 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 comparison of distance relay – Distance protection of a three – Phase line-reasons for inaccuracy of distance relay reach - Three stepped distance protection - Trip contact configuration for the three - Stepped distance protection - Three-stepped protection of three-phase line against all ten shunt faults - Impedance seen from relay side - Three-stepped protection of double end fed lines-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 for acceleration of zone II.; numerical example for a typical distance protection scheme for a transmission line.

4. BUSBAR R PROTECTION 9

Introduction – Differential protection of busbars-external and internal fault - Actual behaviors of a protective CT - Circuit model of a saturated CT - External fault with one CT saturation :need for high impedance – Minimum internal fault that can be detected by the high – Stability ratio of high impedance busbar differential scheme - Supervisory relay-protection of three – Phase busbars-Numerical examples on design of high impedance busbar differential scheme.

5. NUMERICAL PROTECTION 9

Introduction – Block diagram of numerical relay - Sampling theorem-Correlation with a reference wave – Least error squared (LES) technique - Digital filtering-numerical over - Current protection – Numerical transformer differential protection-Numerical distance protection of transmission line

TOTAL : 45 PERIODS

REFERENCES

1. Y.G. Paithankar and S.R Bhide, “Fundamentals of Power System Protection”, Prentice-Hall of India, 2003
2. P.Kundur, “Power System Stability and Control”, McGraw-Hill, 1993.
3. Badri Ram and D.N. Vishwakarma, “Power System Protection and Switchgear”, Tata McGraw- Hill Publishing Company, 2002.

PS 9122 POWER SYSTEM DYNAMICS **L T P C**
3 0 0 3

1. 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 $p\Psi$ terms and speed variations, Simplified model with amortisseurs neglected: two-axis model with amortisseur windings neglected, classical model.

2. 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.

3. 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,

4. 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.

5. 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

REFERENCES

1. P. Kundur, "Power System Stability and Control", McGraw-Hill, 1993.
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.

PS 9123 FLEXIBLE AC TRANSMISSION SYSTEMS L T P C
3 0 0 3

1. INTRODUCTION 9

Reactive power control in electrical power transmission lines -Uncompensated transmission line - series compensation – Basic concepts of static Var Compensator (SVC) – Thyristor Switched Series capacitor (TCSC) – Unified power flow controller (UPFC).

2. STATIC VAR COMPENSATOR (SVC) AND APPLICATIONS 9

Voltage control by SVC – Advantages of slope in dynamic characteristics – Influence of SVC on system voltage – Design of SVC voltage regulator –Modelling of svc for power flow and transient stability – Applications: Enhancement of transient stability – Steady state power transfer – Enhancement of power system damping – Prevention of voltage instability.

3. THYRISTOR CONTROLLED SERIES CAPACITOR (TCSC) AND APPLICATIONS 9

Operation of the TCSC – Different modes of operation – Modelling of TCSC – Variable reactance model – Modelling for Power Flow and stability studies. Applications: Improvement of the system stability limit – Enhancement of system damping-SSR Mitigation.

4. VOLTAGE SOURCE CONVERTER BASED FACTS CONTROLLERS 9

Static Synchronous Compensator (STATCOM) – Principle of operation – V-I Characteristics. Applications: Steady state power transfer-Enhancement of transient stability - Prevention of voltage instability. SSSC-operation of SSSC and the control of power flow –Modelling of SSSC in load flow and transient stability studies. Applications: SSR Mitigation-UPFC and IPFC

5. CO-ORDINATION OF FACTS CONTROLLERS 9

Controller interactions – SVC – SVC interaction – Co-ordination of multiple controllers using linear control techniques – Control coordination using genetic algorithms.

TOTAL : 45 PERIODS

REFERENCES

1. R.Mohan Mathur, Rajiv K.Varma, “Thyristor – Based Facts Controllers for Electrical Transmission Systems”, IEEE press and John Wiley & Sons, Inc.
2. Narain G. Hingorani, “Understanding FACTS -Concepts and Technology of Flexible AC Transmission Systems”, Standard Publishers Distributors, Delhi-110 006
3. K.R.Padiyar,” FACTS Controllers in Power Transmission and Distribution”, New Age International(P) Limited, Publishers, New Delhi, 2008
4. A.T.John, “Flexible A.C. Transmission Systems”, Institution of Electrical and Electronic Engineers (IEEE), 1999.
5. V.K.Sood,HVDC and FACTS controllers – Applications of Static Converters in Power System, APRIL 2004 , Kluwer Academic Publishers.

PS 9124 **RESTRUCTURED POWER SYSTEMS**

LT P C
3 0 0 3

1. OVERVIEW OF KEY ISSUES IN ELECTRIC UTILITIES RESTRUCTURING 9

Restructuring 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 - Market Power - Stranded costs - Transmission Pricing: Contract Path Method, The MW-Mile Method - Congestion Pricing: Congestion Pricing Methods, Transmission Rights - Management of Inter-Zonal/Intra Zonal Congestion: Solution procedure, Formulation of Inter-Zonal Congestion Sub problem, Formulation of Intra-Zonal Congestion Sub problem.

2. ELECTRIC UTILITY MARKETS IN THE UNITED STATES: 9

California Markets: ISO, Generation, Power Exchange, Scheduling Co-coordinator, UDCs, Retailers and Customers, Day-ahead and Hour-Ahead Markets, Block forwards Market, Transmission Congestion Contracts(TCCs) - New York Market: Market operations - PJM interconnection - Ercot ISO - New England ISO - Midwest ISO: MISO's Functions, Transmission Management, Transmission System Security, Congestion Management, Ancillary Services Coordination, Maintenance Schedule Coordination - Summary of functions of U.S. ISOs.

3. OASIS: OPEN ACCESS SAME-TIME INFORMATION SYSTEM: 9

FERC order 889 - Structure of OASIS: Functionality and Architecture of OASIS - Implementation of OASIS Phases: Phase 1, Phase 1-A, Phase 2 - Posting of information: Types of information available on OASIS, Information requirement of OASIS, Users of OASIS - Transfer Capability on OASIS: Definitions, Transfer Capability Issues, ATC Calculation, TTC Calculation, TRM Calculation, CBM Calculation - Transmission Services - Methodologies to Calculate ATC - Experiences with OASIS in some Restructuring Models: PJM OASIS, ERCOT OASIS.

4. ELECTRIC ENERGY TRADING: 9

Essence of Electric Energy Trading - Energy Trading Framework: The Qualifying factors - Derivative Instruments of Energy Trading: Forward Contracts, Futures Contracts, Options, Swaps, Applications of Derivatives in Electric Energy Trading - Portfolio Management: Effect of Positions on Risk Management - Energy Trading Hubs - Brokers in Electricity Trading - Green Power Trading.

5. ELECTRICITY PRICING - VOLATILITY, RISK AND FORECASTING: 9

Electricity Price Volatility: Factors in Volatility, Measuring Volatility - Electricity Price Indexes: Case Study for Volatility of Prices in California, Basis Risk - Challenges to Electricity Pricing: Pricing Models, Reliable Forward Curves - Construction of Forward Price Curves: Time frame for Price Curves, Types of Forward Price Curves – Short-term Price Forecasting: Factors Impacting Electricity Price, Forecasting Methods, Analyzing Forecasting Errors, Practical Data Study.

TOTAL : 45 PERIODS

REFERENCES :

1. Mohammad Shahidehpour and Muwaffaq Almoush, “Restructured Electrical Power Systems Operation, Trading and Volatility,” Marcel Dekkar, Inc, 2001.
2. G.Zaccour, “Deregulation of Electric Utilities”, Kluwer Academic Publishers 1998.
3. M.Illic, F.Galiana and L.Fink, “Power Systems Restructuring : Engineering and Economics”, Kluwer Academic Publishers, 2000.
4. Editor, Loi Lei Lai, “Power System Restructuring and Deregulation : Trading, Performance and Information Technology”, John Wiley and sons Ltd, 2001.
5. K.Bhattacharaya, M.H.J.Bollen and J.E.Daader, “Operation of Restructured Power Systems”, Kluwer Academic Publishers, 2001.
6. F.C.Schweppe, M.C.Caramanis, R.D.Tabors and R.E.Bohn, “Spot Pricing of Electricity”, Kluwer Academic Publishers, 2002.
7. Editors: J.H.Chow F.F. Wu and J.A.Momoh, “Applied Mathematics for Restructured Electric Power Systems: Optimization, Control and Computational Intelligence”, Springer 2004.

PS 9125 POWER SYSTEM SIMULATION LABORATORY-II **L T P C**

0 0 3 2

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

4 Induction motor starting analysis

5 Load flow analysis of two-bus system with STATCOM

6 Transient analysis of two-bus system with STATCOM

7 Available Transfer Capability calculation using an existing load flow program

8. Computation of harmonic indices generated by a rectifier feeding a R-L load

P = 45 Total= 45

PS 9131 PROJECT WORK (PHASE I) **0 0 12 6**

PS 9141 PROJECT WORK (PHASE – II) **0 0 24 12**

HV 9111 ELECTROMAGNETIC FIELD COMPUTATION AND MODELLING L T P C
3 1 0 4

1. INTRODUCTION 9
Review of basic field theory – electric and magnetic fields – Maxwell's equations – Laplace, Poisson and Helmoltz equations – principle of energy conversion – force/torque calculation – Electro thermal formulation.

2. SOLUTION OF FIELD EQUATIONS I 9
Limitations of the conventional design procedure, need for the field analysis based design, problem definition , solution by analytical methods-direct integration method – variable separable method – method of images, solution by numerical methods-Finite Difference Method.

3. SOLUTION OF FIELD EQUATIONS II 9
Finite element method (FEM) – Differential/ integral functions – Variational method – Energy minimization – Discretisation – Shape functions –Stiffness matrix –1D and 2D planar and axial symmetry problem.

4. FIELD COMPUTATION FOR BASIC CONFIGURATIONS 9
Computation of electric and magnetic field intensities– Capacitance and Inductance – Force, Torque, Energy for basic configurations.

5. DESIGN APPLICATIONS 9
Insulators- Bushings – Cylindrical magnetic actuators – Transformers – Rotating machines.

REFERENCES L=45: T=15, Total =60

1. K.J.Binns, P.J.Lawrenson, C.W Trowbridge, "The analytical and numerical solution of Electric and magnetic fields", John Wiley & Sons, 1993.
2. Nathan Ida, Joao P.A.Bastos , "Electromagnetics and calculation of fields", Springer-
   Verlage, 1992.
3. Nicola Biyanchi , "Electrical Machine analysis using Finite Elements", Taylor and Francis Group, CRC Publishers, 2005.
4. S.J Salon, "Finite Element Analysis of Electrical Machines." Kluwer Academic Publishers, London, 1995, distributed by TBH Publishers & Distributors, Chennai, India
5. User manuals of MAGNET, MAXWELL & ANSYS software.
6. Silvester and Ferrari, "Finite Elements for Electrical Engineers" Cambridge University press, 1983.

PE 9111 ANALYSIS OF ELECTRICAL MACHINES

L T P C
3 0 0 3

1. PRINCIPLES OF ELECTROMAGNETIC ENERGY CONVERSION 9

General expression of stored magnetic energy, co-energy and force/ torque – example using single and doubly excited system –Calculation of air gap mmf and per phase machine inductance using physical machine data.

2. REFERENCE FRAME THEORY 9

Static and rotating reference frames – transformation of variables – reference frames – transformation between reference frames – transformation of a balanced set –balanced steady state phasor and voltage equations – variables observed from several frames of reference.

3. DC MACHINES 9

Voltage and toque equations – dynamic characteristics of permanent magnet and shunt DC motors – state equations - solution of dynamic characteristic by Laplace transformation.

4. INDUCTION MACHINES 9

Voltage and toque equations – transformation for rotor circuits – voltage and toque equations in reference frame variables – analysis of steady state operation – free acceleration characteristics – dynamic performance for load and torque variations – dynamic performance for three phase fault – computer simulation in arbitrary reference frame.

5. SYNCHRONOUS MACHINES 9

Voltage and Torque Equation – voltage Equation in arbitrary reference frame and rotor reference frame – Park equations - **rotor angle and angle between rotor** – steady state analysis – dynamic performances for torque variations- dynamic performance for three phase fault – transient stability limit – critical clearing time – computer simulation.

TOTAL : 45 PERIODS

TEXT BOOKS

1. Paul C.Krause, OlegWasyzczuk, Scott S, Sudhoff, “Analysis of Electric Machinery and Drive Systems”, IEEE Press, Second Edition.
2. R.Krishnan, “Electric Motor Drives, Modeling, Analysis and Control” , Prentice Hall of India, 2002

REFERENCES

1. Samuel Seely, “ Eletomechanical Energy Conversion”, Tata McGraw Hill Publishing Company,
2. A.E, Fitzgerald, Charles Kingsley, Jr, and Stephan D, Umanx, “ Electric Machinery”, Tata McGraw Hill, 5th Edition, 1992

PE 9113 ANALYSIS OF INVERTERS L T P C
3 0 0 3

1. SINGLE PHASE INVERTERS 12

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

2. THREE PHASE VOLTAGE SOURCE INVERTERS 9

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

3. CURRENT SOURCE INVERTERS 9

Operation of six-step thyristor inverter – inverter operation modes – load – commutated inverters – Auto sequential current source inverter (ASCI) – current pulsations – comparison of current source inverter and voltage source inverters

4. MULTILEVEL INVERTERS 9

Multilevel concept – diode clamped – flying capacitor – cascade type multilevel inverters - Comparison of multilevel inverters - application of multilevel inverters

5. RESONANT INVERTERS 6

Series and parallel resonant inverters - voltage control of resonant inverters – Class E resonant inverter – resonant DC – link inverters.

TOTAL : 45 PERIODS

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,Undeland and Robbin, “Power Electronics: converters, Application and design” John Wiley and sons.Inc,Newyork,1995.
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.

HV 9124 EHV POWER TRANSMISSION **L T P C**
3 0 0 3

1.INTRODUCTION **9**

Standard transmission voltages – different configurations of EHV and UHV lines – average values of line parameters – power handling capacity and line loss – costs of transmission lines and equipment – mechanical considerations in line performance.

2.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 – resistance and inductance of ground return, numerical example involving a typical 400/220kV line using line constant program.

3.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.

4. CORONA EFFECTS **9**

Power losses and audible losses: I^2R loss and corona loss - audible noise generation and characteristics - limits for audible noise - Day-Night equivalent noise level- radio interference**:** corona pulse generation and properties - limits for radio interference fields.

5.ELECTROSTATIC FIELD 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.

TOTAL : 45 PERIODS

REFERENCES:

1. Rakosh Das Begamudre, “Extra High Voltage AC Transmission Engineering”, Second Edition, New Age International Pvt. Ltd., 1990.
2. Power Engineer’s Handbook, Revised and Enlarged 6^{th} Edition, TNEB Engineers’ Association, October 2002.
3. Microtran Power System Analysis Corporation, Microtran Reference Manual, Vancouver Canada. (Website: www.microtran.com).

EB 9123 SPECIAL ELECTRICAL MACHINES **L T P C**
3 0 0 3

1. SYNCHRONOUS RELUCTANCE MOTORS 9

Constructional features: axial and radial air gap Motors. Operating principle, reluctance torque – phasor diagram, motor characteristics – Linear induction machines.

2. STEPPING MOTORS 9

Constructional features, principle of operation, modes of excitation torque production in Variable Reluctance (VR) stepping motor, Dynamic characteristics, Drive systems and circuit for open loop control, Closed loop control of stepping motor.

3. SWITCHED RELUTANCE MOTORS 9

Constructional features-principle of operation-Torque equation-Power Controllers-Characteristics and control Microprocessor based controller.

4. PERMANENT MAGNET SYNCHRONOUS MOTORS 9

Principle of operation, EMF, power input and torque expressions, Phasor diagram, Power controllers, Torque speed characteristics, Self control, Vector control, Current control schemes.

5. PERMANENT MAGNET BRUSHLESS DC MOTORS 9

Commutation in DC motors, Difference between mechanical and electronic commutators, Hall sensors, Optical sensors, Multiphase Brushless motor, Square wave permanent magnet brushless motor drives, Torque and emf equation, Torque-speed characteristics, Controllers-Microprocessor based controller.

TOTAL : 45 PERIODS

TEXT BOOKS

1. Miller, T.J.E. “Brushless permanent magnet and reluctance motor drives ", Clarendon Press, Oxford, 1989.
2. Kenjo, T, “Stepping motors and their microprocessor control ", Clarendon Press, Oxford, 1989.
3. LIM

REFERENCES

1. Kenjo, T and Naganori, S “Permanent Magnet and brushless DC motors ", Clarendon Press, Oxford, 1989.
2. Kenjo, T. Power Electronics for the microprocessor Age, 1989.
3. B.K. Bose, “Modern Power Electronics & AC drives”
4. R.Krishnan, “Electric Motor Drives – Modeling, Analysis and Control”, Prentice-Hall of India Pvt. Ltd., New Delhi, 2003

PE 9152 POWER QUALITY L T P C
3 0 0 3

1. 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.

2. NON-LINEAR LOADS 9

Single phase static and rotating AC/DC converters, Three phase static AC/DC converters, Battery chargers, Arc furnaces, Fluorescent lighting, pulse modulated devices, Adjustable speed drives.

3. MEASUREMENT AND ANALYSIS METHODS 9

Voltage, Current, Power and Energy measurements, power factor measurements and definitions, event recorders, Measurement Error – Analysis: Analysis in the periodic steady state, Time domain methods, Frequency domain methods: Laplace's, Fourier and Hartley transform – The Walsh Transform – Wavelet Transform.

4. ANALYSIS AND CONVENTIONAL MITIGATION METHODS 9

Analysis of power outages, Analysis of unbalance: Symmetrical components of phasor quantities, Instantaneous symmetrical components, Instantaneous real and reactive powers, Analysis of distortion: On–line extraction of fundamental sequence components from measured samples – Harmonic indices – Analysis of voltage sag: Detorit Edison sag score, Voltage sag energy, Voltage Sag Lost Energy Index (VSLEI)- Analysis of voltage flicker, Reduced duration and customer impact of outages, Classical load balancing problem: Open loop balancing, Closed loop balancing, current balancing, Harmonic reduction, Voltage sag reduction.

5. POWER QUALITY IMPROVEMENT 9

Utility-Customer interface –Harmonic filters: passive, Active and hybrid filters – Custom power devices: Network reconfiguring Devices, Load compensation using DSTATCOM, Voltage regulation using DSTATCOM, protecting sensitive loads using DVR, UPQC –control strategies: P-Q theory, Synchronous detection method – Custom power park –Status of application of custom power devices.

TOTAL : 45 PERIODS

TEXT BOOKS

1. Arindam Ghosh "Power Quality Enhancement Using Custom Power Devices", Kluwer Academic Publishers, 2002
2. G.T.Heydt, "Electric Power Quality", Stars in a Circle Publications, 1994(2nd edition)
3. Power Quality - R.C. Duggan
4. Power system harmonics –A.J. Arrillga
5. Power electronic converter harmonics –Derek A. Paice

PS 9151 POWER SYSTEM PLANNING AND RELIABILITY

L T P C
3 0 0 3

1. 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.

2. GENERATION SYSTEM RELIABILITY ANALYSIS 9

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

3. 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.

4. 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.

5. 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

REFERENCES:

1. Proceeding of work shop on energy systems planning & manufacturing CI.

2. R.L .Sullivan, " Power System Planning",.

3. Roy Billinton and Allan Ronald, "Power System Reliability."

4. Turan Gonen, Electric power distribution system Engineering 'McGraw Hill,1986

ET 9159 ADVANCED DIGITAL SIGNAL PROCESSING **L T P C**
3 0 0 3

1. INTRODUCTION **9**

Mathematical description of change of sampling rate – Interpolation and Decimation, Filter implementation for sampling rate conversion – direct form FIR structures, DTFT, FFT, Wavelet transform and filter bank implementation of wavelet expansion of signals

2. ESTIMATION AND PREDICTION TECHNIQUES **9**

Discrete Random Processes – Ensemble averages, Stationary processes, Autocorrelation and Auto covariance matrices. Parseval's Theorem, Wiener-Khintchine Relation – Power Spectral Density. AR, MA, ARMA model based spectral estimation. Parameter Estimation, Linear prediction – Forward and backward predictions, Least mean squared error criterion – Wiener filter for filtering and prediction, Discrete Kalman filter.

3. DIGITAL SIGNAL PROCESSOR **9**

Basic Architecture – Computational building blocks, MAC, Bus Architecture and memory, Data Addressing, Parallelism and pipelining, Parallel I/O interface, Memory Interface, Interrupt, DMA.

4. APPLICATION OF DSP **9**

Design of Decimation and Interpolation Filter, FFT Algorithm, PID Controller, Application for Serial Interfacing, DSP based Power Meter, Position control.

5. VLSI IMPLEMENTATION **9**

Basics on DSP sytem architecture design using VHDL programming, Mapping of DSP algorithm onto hardware, Realisation of MAC & Filter structure.

TOTAL : 45 PERIODS

REFERENCES:

1. Bernard Widrow, Samuel D. Stearns, “Adaptive Signal Processing”, Pearson Education, third edition, 2004.
2. Dionitris G. Manolakis, Vinay K. Ingle, Stepen M. Kogon,”Statistical & Adaptive signal processing, spectral estimation, signal modeling, Adaptive filtering & Array processing”, McGraw-Hill International edition 2000.
3. Monson H. Hayes, “Statistical Digital Signal Processing and Modelling”, John Wiley and Sons, Inc.,
4. John G. Proaks, Dimitris G. Manolakis, “Digital Signal Processing”, Pearson Education 2002.
5. S. Salivahanan, A. Vallavaraj and C. Gnanapriya “Digital Signal Processing”, TMH,2000.
6. Avatar Sing, S. Srinivasan, “Digital Signal Processing- Implementation using DSP Microprocessors with Examples from TMS320C54xx”, Thomson India, 2004.
7. Lars Wanhammer, “DSP Integrated Circuits”, Academic press, 1999,New York.
8. Ashok Ambardar,”Digital Signal Processing: A Modern Introduction”,Thomson India edition, 2007.
9. Lars Wanhammer, “DSP Integrated Circuits”, Academic press, 1999,New York.

CO 9113 CONTROL SYSTEM DESIGN **L T P C**
3 1 0 4

1. CONVENTIONAL DESIGN METHODS 9

Design specifications- PID controllers and compensators- Root locus based design-Bode based design-Design examples

2. DESIGN IN DISCRETE DOMAIN 9

Sample and Hold-Digital equivalents-Impulse and step invariant transformations-Methods of discretisation-Effect of sampling- Direct discrete design – discrete root locus
Design examples

3. OPTIMAL CONTROL 9

Formation of optimal control problems-results of Calculus of variations- Hamiltonian formulation-solution of optimal control problems- Evaluation of Riccati's equation
State and output Regulator problems-Design examples

4. DISCRETE STATE VARIABLE DESIGN 9

Discrete pole placement- state and output feedback-estimated state feedback-discrete optimal control- dynamic programming-Design examples

5. STATE ESTIMATION 9

State Estimation Problem -State estimation- Luenberger's observer-noise characteristics- Kalman-Bucy filter-Separation Theorem-Controller Design-Wiener filter-Design examples.

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

REFERENCES

1. M. Gopal "Modern control system Theory" New Age International, 2005.
2. Benjamin C. Kuo "Digital control systems", Oxford University Press, 2004.
3. G. F. Franklin, J. D. Powell and A. E. Naeini "Feedback Control of Dynamic Systems", PHI (Pearson), 2002.
4. Graham C. Goodwin, Stefan F. Graebe and Mario E. Salgado "Control system Design", PHI (Pearson), 2003.
5. G. F. Franklin, J. D. Powell and M Workman, "Digital Control of Dynamic Systems", PHI (Pearson), 2002.
6. B.D.O. Anderson and J.B. Moore., 'Optimal Filtering', Prentice hall Inc., N.J., 1979.
7. Loan D. Landau, Gianluca Zito," Digital Control Systems, Design, Identification and Implementation", Springer, 2006.

CO 9155 OPTIMAL CONTROL AND FILTERING **L T P C**
3 0 0 3

1. INTRODUCTION **9**

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

2. LQ CONTROL PROBLEMS AND DYNAMIC PROGRAMMING **9**

Linear optimal regulator problem – Matrix Riccatti equation and solution method – Choice of weighting matrices – Steady state properties of optimal regulator – Linear tracking problem – LQG problem – Computational procedure for solving optimal control problems – Characteristics of dynamic programming solution – Dynamic programming application to discrete and continuous systems – Hamilton Jacobi Bellman equation.

3. NUMERICAL TECHNIQUES FOR OPTIMAL CONTROL **9**

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

4. FILTERING AND ESTIMATION **9**

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

5. KALMAN FILTER AND PROPERTIES **9**

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

TOTAL : 45 PERIODS

REFERENCES:

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

PS9152 ADVANCED POWER SYSTEM DYNAMICS **L T P C**
3 0 0 3

1. TRANSIENT STABILITY ANALYSIS [1,2,3] 9

Review of numerical integration methods: Euler and Fourth Order Runge-Kutta methods, Numerical stability and implicit methods, Simulation of Power System Dynamic response: Structure of Power system Model, Synchronous machine representation: equations of motion, rotor circuit equations, stator voltage equations, Thevenin's and Norton's equivalent circuits, Excitation system representation, Transmission network and load representation, Overall system equations and their solution: Partitioned – Explicit and Simultaneous-implicit approaches, treatment of discontinuities, Simplified Transient Stability Simulation using implicit integration method.

2. SUBSYNCHRONOUS OSCILLATIONS [1] 9

Introduction – 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.

3. SUBSYSNCHRONOUS RESONANCE (SSR) [1,4] 9

Subsysnchronous Resonance (SSR): Characteristics of series –Compensated transmission systems – Self-excitation due to induction generator effect – Torsional interaction resulting in SSR – Analytical Methods – Numerical examples illustrating instability of subsynchronous oscillations – Impact of Network-Switching Disturbances: Steady-state switching – Successive network-Switching disturbances – Torsional Interaction Between Closely Coupled Units; time-domain simulation of subsynchronous resonance – EMTP with detailed synchronous machine model

4. TRANSMISSION, GENERATION AND LOAD ASPECTS OF VOLTAGE STABILITY ANALYSIS [5] 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.

5 . 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

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. AU Power Lab Laboratory Manuals, Anna University, pp : 7-1 to 7-12, May 2004.
4. H. W. Dommel, EMTP THEORY BOOK, Microtran Power System Analysis Corporation, Second Edition, 1996.
5. T.V. Cutsem and C.Vournas, “Voltage Stability of Electric Power Systems”, Kluwer publishers,1998.

CO 9157 SYSTEM IDENTIFICATION AND ADAPTIVE CONTROL

L T P C
3 0 0 3

1. 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'.

2. 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.

3. NON-LINEAR IDENTIFICATION AND MODEL VALIDATION 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.

4. 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.

5. CASE STUDIES 9

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

TOTAL : 45 PERIODS

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.

PS 9153 INDUSTRIAL POWER SYSTEM ANALYSIS AND DESIGN **L T P C 3 0 0 3**

1. MOTOR STARTING STUDIES 9

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

2. POWER FACTOR CORRECTION STUDIES 9

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

3. HARMONIC ANALYSIS 9

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

4. FLICKER ANALYSIS 9

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

5. GROUND GRID ANALYSIS 9

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

TOTAL : 45 PERIODS

REFERENCES

1. Ramasamy Natarajan, ”Computer-Aided Power System Analysis”, Marcel Dekker Inc., 2002.

PS 9154 HIGH VOLTAGE DIRECT CURRENT TRANSMISSION **L T P C**
3 0 0 3

1. 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.

2. 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.

3. MULTITERMINAL DC SYSTEMS 9

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

4. 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 - Case studies.

5. SIMULATION OF HVDC SYSTEMS 9

Introduction **–** System simulation: Philosophy and tools **–** HVDC system simulation **–** Modeling of HVDC systems for digital dynamic simulation – Dynamic intraction between DC and AC systems.

TOTAL : 45 PERIODS

REFERENCES

1. K.R.Padiyar, , "HVDC Power Transmission Systems", New Age International (P) Ltd., New Delhi, 2002.
2. J.Arrillaga, , "High Voltage Direct Current Transmission", Peter Pregrinus, London, 1983.
3. P. Kundur, "Power System Stability and Control", McGraw-Hill, 1993.
4. Erich Uhlmann, " Power Transmission by Direct Current", BS Publications, 2004.
5. V.K.Sood,HVDC and FACTS controllers – Applications of Static Converters in Power System, APRIL 2004 , Kluwer Academic Publishers.

PS 9155 WIND ENERGY CONVERSION SYSTEMS L T P C
3 0 0 3

1. INTRODUCTION 9

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

2. 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.

3. 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.

4. 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 modeling - Variable speed variable frequency schemes.

5. GRID CONNECTED SYSTEMS 9

Stand alone and Grid Connected WECS system-Grid connection Issues-Machine side & Grid side controllers-WECS in various countries

TOTAL : 45 PERIODS

REFERENCES

1. L.L.Freris "Wind Energy conversion Systems", Prentice Hall, 1990
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. S.Heir "Grid Integration of WECS", Wiley 1998.

CO 9151 SOFT COMPUTING TECHNIQUES L T P C
3 0 0 3

1. INTRODUCTION 9

Approaches to intelligent control. Architecture for intelligent control. Symbolic reasoning system, rule-based systems, the AI approach. Knowledge representation. Expert systems.

2.ARTIFICIAL NEURAL NETWORKS 9

Concept of Artificial Neural Networks and its basic mathematical model, McCulloch-Pitts neuron model, simple perceptron, Adaline and Madaline, Feed-forward Multilayer Perceptron. Learning and Training the neural network. Data Processing: Scaling, Fourier transformation, principal-component analysis and wavelet transformations. Hopfield network, Self-organizing network and Recurrent network. Neural Network based controller

3. FUZZY LOGIC SYSTEM 9

Introduction to crisp sets and fuzzy sets, basic fuzzy set operation and approximate reasoning. Introduction to fuzzy logic modeling and control. Fuzzification, inferencing and defuzzification. Fuzzy knowledge and rule bases. Fuzzy modeling and control schemes for nonlinear systems. Self-organizing fuzzy logic control. Fuzzy logic control for nonlinear time-delay system.

4. 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 and anD-colony search techniques for solving optimization problems.

5. APPLICATIONS 9

GA application to power system optimisation problem, Case studies: Identification and control of linear and nonlinear dynamic systems using Matlab-Neural Network toolbox. Stability analysis of Neural-Network interconnection systems. Implementation of fuzzy logic controller using Matlab fuzzy-logic toolbox. Stability analysis of fuzzy control systems.

TOTAL : 45 PERIODS

REFERENCES

1. Jacek.M.Zurada, "Introduction to Artificial Neural Systems", Jaico Publishing House, 1999.
2. KOSKO,B. "Neural Networks And Fuzzy Systems", Prentice-Hall of India Pvt. Ltd., 1994.
3. KLIR G.J. & FOLGER T.A. "Fuzzy sets, uncertainty and Information", Prentice-Hall of India Pvt. Ltd., 1993.
4. Zimmerman H.J. "Fuzzy set theory-and its Applications"-Kluwer Academic Publishers, 1994.
5. Driankov, Hellendroon, "Introduction to Fuzzy Control", Narosa Publishers.

PE 9154 POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS LT P C
3 0 0 3

1. 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: Solar, wind, ocean, Biomass, Fuel cell, Hydrogen energy systems and hybrid renewable energy systems.

2. ELECTRICAL MACHINES FOR RENEWABLE ENERGY CONVERSION 9

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

3. POWER CONVERTERS 9

Solar: Block diagram of solar photo voltaic system -Principle of operation: 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.

4. ANALYSIS OF WIND AND PV SYSTEMS 9

Stand alone 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

5. HYBRID RENEWABLE ENERGY SYSTEMS 9

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

TOTAL : 45 PERIODS

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.

EB 9152 APPLICATIONS OF MEMS TECHNOLOGY **L T P C**
3 0 0 3

1. MEMS: MICRO-FABRICATION, MATERIALS AND ELECTRO-MECHANICAL CONCEPTS **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.

2. ELECTROSTATIC SENSORS AND ACTUATION **9**

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

3. THERMAL SENSING AND ACTUATION **9**

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

4. PIEZOELECTRIC SENSING AND ACTUATION **9**

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

5. CASE STUDIES **9**

Piezoresistive sensors, Magnetic actuation, Micro fluidics applications, Medical applications, Optical MEMS.

TOTAL : 45 PERIODS

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.