PMA15103 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

PPS15101 ADVANCED 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.

PPS15102 ADVANCED POWER SYSTEM OPERATION AND CONTROL L T P C
3 0 0 3

1 REACTIVE POWER AND VOLTAGE CONTROL **9**

Production and absorption of reactive power- Methods of Voltage Control – Shunt reactors – Shunt Capacitors – Series Capacitors – Synchronous condensers – Static Var systems – Principles of Transmission system compensation – Modeling of reactive compensating devices – Application of tap changing transformers to transmission systems – Distribution system voltage regulation – Modelling of transformer ULTC control systems.

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. INTERCHANGE OF POWER AND ENERGY **9**

Economy interchange between interconnected utilities - interchange evaluation with unit commitment - multiple - utility interchange transactions - power pools - the energy broker system - allocating pool savings - transmission effects and issues - transfer limitations - wheeling - rates for transmission services in multiparty utility transactions - transactions involving non-utility parties.

5. CONTROL OF POWER SYSTEMS **9**

Introduction to state estimation- 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.

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.

PPS15103 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

REFERENCES

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

PPS15104 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.

PPS15105P 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 software: Energisation of a long distributed-parameter line
8. Analysis of switching surge using software: Computation of transient recovery voltage
9. State estimation in power system.
10. Analysis of rotor angle stability using swing equation

P = 45 Total= 45

PPS15201 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 – construction and working principle of impedance relay , Reactance relay, Mho relay . Comparison of relays

4. BUSBAR 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. Introduction to synchrophasor technology,phasor measurement unit.-Blockout study in India using PMU

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.

4.Black burl “power system protection”

PPS15202 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 stability using swing equation

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, Power System Stabiliser: Block diagram with AVR and PSS, Block diagram of PSS with description, 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, Effect of multiband PSS(MBPSS)

5. ENHANCEMENT OF SMALL SIGNAL STABILITY 9

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. R.Ramanujam "Power System Dynamics: Analysis and Simulation". PHI Learning Pvt. Ltd., 2009

3. P.M Anderson and A.A Fouad, "Power System Control and Stability", Iowa State University Press, Ames, Iowa 1978.

4. Edward Wilson Kimbark "POWER SYSTEM STABILITY" IEEE press 1995

5. 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.

PPS15203 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.

PPS15204 RESTRUCTURED POWER SYSTEMS L T P C

3 0 0 3

UNIT I: FUNDAMENTALS OF POWER MARKETS 9

Fundamentals and structure of Restructured Power Market – Wheeling – Market Power - Power exchange and pool markets - Independent System Operator (ISO) – components - role of ISO - Operating Experiences of Restructured Electricity Markets in various Countries (UK, Australia, Europe, US, Asia).

UNIT II: TRANSMISSION CHALLENGES 9

Transmission expansion in the New Environment – Introduction – Role of transmission planning – Transmission Capacity – Total Transfer Capability (TTC) – Computational procedure - Margins – Available transfer capability (ATC) – Principles – Constraints - Methods to compute ATC.

UNIT III: CONGESTION MANAGEMENT AND ANCILLARY SERVICES 9

Concept of Congestion Management – Methods to relieve the congestion - Inter and Intra zonal Congestion Management – Generation Rescheduling - Locational Marginal Pricing – Financial Transmission Right - Ancillary Services.

UNIT IV: TRANSMISSION PRICING 9

Transmission pricing methods - Postage stamp - Contract path - MW-mile – MVA mile – Distribution Factor method – Tracing method - Short run marginal cost (SRMC) – Generator Ramping and Opportunity Costs.

UNIT V: INDIAN POWER MARKET 9

Current Scenario – Regions – Salient features of Indian Electricity Act 2003 – Regulatory and Policy development in Indian power Sector – Availability based tariff – Necessity – Working Mechanism – Unscheduled Interchange Rate – Operation of Indian Power Exchange.

REFERENCES:

1. M. Shahidehpour and M. Alomoush, “Restructuring Electrical Power Systems”, Marcel Decker Inc., 2001.
2. M. Shahidehpour, H. Yamin and Z. Li, “Market Operations in Electric Power Systems”, John Wiley & Sons, Inc., 2002.
3. Kankar Bhattacharya, Math H.J. Bollen and Jaap E. Daalder, “Operation of Restructured Power Systems”, Kluwer Academic Publishers, 2001.
4. Loi Lei Lai, “Power system Restructuring and Regulation”, John Wiley sons, 2001.
5. Scholarly Transaction Papers, Utility and Power Exchange web sites.

PPS15205P 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 Load flow and Transient analysis of two-bus system with STATCOM
5 TTC and ATC calculation using an existing load flow program
6. Computation of harmonic indices generated by a rectifier feeding a R-L load
7. Bilateral and multilateral transactions in power system.
8. Load flow analysis by SSSC
9. D-Q analysis of synchronous machine
10. Congestion management

P = 45 Total= 45

PPS15301P PROJECT WORK (PHASE I) 0 0 12 6

PPS15401P PROJECT WORK (PHASE – II) 0 0 24 12

PPS15151 MODELING AND 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

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

PPS15152 POWER CONVERTERS FOR RENEWABLE ENERGY SOURCES L T 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 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.

3 VOLTAGE SOURCE INVERTERS 9

Introduction of VSI & CSI - Principle of operation of half and full bridge inverters – Performance parameters – Voltage control of single phase inverters using various PWM techniques – Three Phase Inverters with 180 degree and 120 degree conduction modes – voltage control of three phase inverters: single, multi pulse, sinusoidal, space vector modulation techniques.

4 CURRENT SOURCE INVERTERS AND MULTILEVEL INVERTER 9

Load commutated inverters – Auto sequential current source inverters (ASCI) – current pulsations (single & Three Phase) – comparison of current source inverter and voltage source inverters. Multilevel concept – diode clamped – flying capacitor – cascade type multilevel inverters - Comparison of multilevel inverters - application of multilevel inverters

5 RENEWABLE ENERGY SYSTEMS 9

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

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. Ned Mohan,Undeland and Robbin, "Power Electronics: converters, Application and design" John Wiley and sons.Inc,Newyork,1995.
5. P.S.Bimbhra, "Power Electronics", Khanna Publishers, Eleventh Edition, 2003.

PPS15153 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

PPS15251 **POWER SYSTEM ECONOMICS** **L T P C**

3 0 0 3

UNIT-I: ECONOMIC CONSIDERATIONS **9**

Cost of electrical energy - Expressions for cost of electrical energy – Capital-interest – Depreciation - Different methods - Factors affecting cost of operation - Number and size of generating units - Importance of high load factor - Importance of power factor improvement - Most economical power factor - Meeting the KW demand on power stations - Power system tariffs – Regions and structure of Indian Power System.

UNIT-II: ECONOMIC DISPATCH **9**

Modeling of Cost Rate Curves – Economic Dispatch Calculation - Losses neglected, with generator Real and Reactive power limits; Losses included - Losses of economy in incremental cost data - Problems - Generator Capability Curve – Effect of Ramping rates – Prohibited Operating Zones - Automatic Load dispatch in Power Systems.

UNIT-III: ECONOMIC OPERATION 9

General loss formula - Evolution of incremental transmission loss rate - Method of calculation of loss coefficients – Systematic development of transmission loss formula - Transmission loss as a function of plant generation – Participation Factor - Non – Smooth Fuel Functions (Quadratic, Valve point loading, CCCP, Multiple Fuel) – Problems - Introduction to Artificial Intelligence Techniques for solving ELD problems.

UNIT- IV: ECONOMIC CONTROL 9

Interconnected operation - Economic operation of hydro thermal power plants - Gradient approach – Newton's method - Modeling and solution approach to short term and long term Hydro-Thermal scheduling problem using Dynamic Programming.

UNIT-V: OPTIMAL POWER FLOW AND FUNDAMENTALS OF MARKETS 9

Problem formulation - Cost minimization - Loss minimization - Solution using NLP and successive LP methods – Constraints - DC and AC OPF (Real and Reactive Power Dispatch) – Fundamentals of Markets – Efficiency and Equilibrium - Modeling of consumers and producers bids – Global welfare – Dead Loss.

REFERENCES:

1. Allen J Wood and B F Wollenberg, "Power Generation, Operation and Control", John Wiley & Sons, New York, 2010.
2. Hadi Saadat, “Power System Analysis”, Second Edition, Tata McGraw Hill Publishers, 2007.
3. Steven Stoft, “Power System Economics”, John Wiley & Sons, 2000.
4. Daniel S. Kirschen and Goran Strbac, “Power System Economics”, John Wiley & Sons, Ltd, 2004.
5. Scholarly Transaction Papers.

PPS15252 CONTROL SYSTEM DESIGN **L T P C**

3 0 0 3

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.

TOTAL : 45 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.

PPS15253 EHVAC 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 6th Edition, TNEB Engineers’ Association, October 2002.
3. Microtran Power System Analysis Corporation, Microtran Reference Manual, Vancouver Canada. (Website: www.microtran.com).

PPS15254 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.

PPS15255 ENERGY MANAGEMENT AND AUDITING L T P C

3 0 0 3

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.

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.

III – ENERGY MANAGEMENT FOR MOTORS, SYSTEMS, AND ELECTRICAL EQUIPMENTS (9)

Systems and equipment – electric motors – transformers and reactors – capacitors and synchronous machines.

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.

V – LIGHTING SYSTEMS AND 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.

REFERENCES

1. Eastop T.D and Croft D.R, “*Energy Efficiency for Engineers and Technologists*”, Logman Scientific & Technical, 1990.
2. Reay D.A., “*Industrial Energy Conservation*”, first edition, Pergamon Press, 1977.
3. IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities, IEEE, 1996.
4. Amit K. Tyagi, “*Handbook on Energy Audits and Management*”, TERI, 2003.
5. Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, “*Guide to Energy Management*”, Fifth Edition, The Fairmont Press, Inc., 2006.

PPS15256 **POWER DISTRIBUTION SYSTEMS** **L T P C**

3 0 0 3

I - DISTRIBUTION SYSTEM PLANNING AND DESIGN (9)

Distribution system planning Short term planning, Long term planning, dynamic planning, Sub-transmission and substation design. Sub-transmission networks configurations, Substation bus schemes, Distribution substations ratings, Service areas calculations, Substation application curves.

II - DISTRIBUTED GENERATIONS SYSTEMS (9)

Distributed Generation Standards, DG potential, Definitions and terminologies; current status and future trends, Technical and economical impacts of DG Technologies, DG from renewable energy sources, DG from non-renewable energy sources.

III - DISTRIBUTED GENERATION EVALUATION (9)

Distributed generation applications, Operating Modes, Base load; peaking; peak shaving and emergency power, Isolated, momentary parallel and grid connection.

IV - DISTRIBUTION SYSTEM RELIABILITY ANALYSIS (9)

Primary and secondary system design considerations Primary circuit configurations, Primary feeder loading, secondary networks design Economic design of secondary's, Unbalance loads and voltage considerations.

V - DISTRIBUTION SYSTEM AUTOMATION AND CONTROL (9)

Distribution system performance and operation Distribution automation and control, Voltage drop calculation for distribution networks, Power loss Calculation, Application of capacitors to distribution systems, Application of voltage regulators to distribution systems.

REFERENCES

1. Anthony J. Pansini "*Electrical Distribution Engineering*", CRC Press, 2005.
2. H Lee Willis, "*Distributed Power Generation Planning and Evaluation*", CRC Press, 2000.
3. James A Momoh, "*Electric Power Distribution Automation Protection and Control*" CRC Press, 2007.
4. James J. Burke "*Power distribution engineering: fundamentals and applications*", CRC Press, 2004.
5. A. Pabla, *"Electric Power Distribution",* McGraw-Hill, 2005.

PPS15351 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 **–C**ompensated 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.

PPS15352	SMART GRID	L T P C
		3 0 0 3

1.INTRODUCTION TO SMART GRID

Evolution of Electric Grid – Need for smart grid – Difference between conventional & smart grid – Overview of enabling technologies – International experience in smart grid deployment efforts – smart grid road map for INDIA – smart grid architecture

2.WIDE AREA MONITORING SYSTEM

Fundamentals of synchrophasor technology – concept and benefits of wide area monitoring system – Structure and functions of Phasor Measuring Unit (PMU) and Phasor Data Concentrator (PDC) – Road Map for synchrophasor applications (NAPSI) – Operational experience and Blackout analysis using PMU

3.SMART METERS

Features and functions of smart meters – Functional specification – category of smart meters – AMR and AMI drivers and benefits – AMI protocol – Demand Side Integration: Peak load, Outage and Power Quality management

4.INFORMATION AND COMMUNICATION TECHNOLOGY

Overview of smart grid communication system – Modulation and Demodulation techniques: Radio communication – Mobile communication – Power line communication – Optical fibre communication – Communication protocol for smart grid

5.SMART GRID APPLICATIONS

Overview and concept of renewable integration – role of protective relaying in smart grid – House Area Network – Advanced Energy Storage Technology: Flow battery – Fuel cell – SMES – Super capacitors – Plug – in Hybrid electric Vehicles – Cyber Security requirements – Smart grid information model

References

1. “Smart Grid Technology and Applications” by Janaka Ekanayake, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, Nick Jenkins, John Wiley & Sons Publication, 2012.
2. “Smart Grid Primer”, Published by Power Grid Corporation of India Limited, September 2013.
3. “Smart grid – integrating renewable, distributed and efficient energy”, Fereidoon.P.sioshansi, Academic Press, 2011.
4. “Smart Grids: Infrastructure, Technology and Solutions” Edited by Stuart Borlase, CRC Press Publication, 2013.

PPS15353 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.

PPS15354 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.

PPS15355 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.

PPS15356 SOLAR AND ENERGY STORAGE SYSTEMS **L T P C**
3 0 0 3

I INTRODUCTION **9**

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

II STAND ALONE PV SYSTEM **9**

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

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

IV ENERGY STORAGE SYSTEMS **9**

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

V APPLICATIONS **9**

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

REFERENCES:

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.
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.

PPS15357 **OPTIMIZATION TECHNIQUES** **L T P C**
3 0 0 3

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**

REFERENCES:

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

PPS15358 **POWER SYSTEM STABILITY** **L T P C**

3 0 0 3

1. INTRODUCTION TO STABILITY **9**

Power system stability considerations – definitions-classification of stability-rotor angle and voltage stability-synchronous machine representation –classical model-load modeling concepts-modeling of excitation systems-modeling of prime movers.

2.TRANISIENT STABILITY **9**

Transient stability-swing equation-equal area criterion-solution of swing equation-Numerical methods -Euler method-Runge-Kutte method-critical clearing time and angle-effect of excitation system and governors-Multimachine stability –extended equal area criterion-transient energy function approach.

3.SMALL SIGNAL STABIITY **9**

Small signal stability – state space representation – eigen values- modal matrices-small signal stability of single machine infinite bus system – synchronous machine classical model representation-effect of field circuit dynamics-effect of excitation system-small signal stability of multimachine system.

4.VOLTAGE STABILITY **9**

Voltage stability – generation aspects - transmission system aspects – load aspects – PV curve – QV curve – PQ curve – analysis with static loads – loadability limit - sensitivity analysis-continuation power flow analysis - instability mechanisms-examples.

5.STABILITY IMPROVEMENT **9**

Methods of improving stability – transient stability enhancement – high speed fault clearing – steam turbine fast valving-high speed excitation systems- small signal stability enhancement-power system stabilizers – voltage stability enhancement – reactive power control. **45 PERIODS**

REFERENCES

1.Kundur, P.Power System Stability and Control‟, McGraw-Hill International Editions, 1994.

2.Anderson, P.M. and Fouad, A.A., „Power System Control and Stability‟, Galgotia Publications, New Delhi, 2003.

3. Van Cutsem, T. and Vournas, C., „Voltage Stability of Electric Power Systems‟, Kluwer Academic Publishers, 1998.

PPS15359 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.