M.Tech. Programme

in

POWER SYSTEMS

SYLLABUS

FOR

CREDIT BASED CURRICULUM

(Applicable for 2011 batch onwards)

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, TIRUCHIRAPPALLI

The total minimum credits required for completing the M.Tech. Programme in

Power Systems is 62

SEMESTER – I

CODE	COURSE OF STUDY	L	T	P	C
MA603	Optimization Techniques	3	0	0	3
EE601	Advanced Power System Analysis	3	0	0	3
EE603	Power Conversion Techniques	3	0	0	3
EE605	Power System Stability	3	0	0	3
	Elective I	3	0	0	3
	Elective II	3	0	0	3
	Total	18	0	0	18

SEMESTER - II

CODE	COURSE OF STUDY	L	T	P	C
EE602	Power System Operation and Control	3	0	0	3
EE604	High Voltage DC Transmission	3	0	0	3
EE606	Flexible AC Transmission Systems	3	0	0	3
	Elective III	3	0	0	3
	Elective IV	3	0	0	3
	Elective V	3	0	0	3
EE608	Power System Simulation Lab	0	0	3	2
	Total	18	0	3	20

SEMESTER III

CODE	COURSE OF STUDY	L	T	P	C
EE647	Project Work	0	0	24	12

SEMESTER IV

CODE	COURSE OF STUDY	L	T	P	C
EE648	Project Work	0	0	24	12

For the elective courses, a student may take a maximum of two courses from other Post Graduate programs.

ELECTIVES

CODE	COURSE OF STUDY	L	T	P	C
Group I elective subjects recommended for 1st semester					
EE611	Industrial Control Electronics	3	0	0	3
EE613	System Theory	3	0	0	3
EE615	Analysis and design of Artificial Neural Networks	3	0	0	3
EE617	Digital Signal Processing & Applications	3	0	0	3
EE619	Digital System Design	3	0	0	3

Any one course from other department

Group II elective subjects recommended for 2nd semester

EE612	Power Electronic Drives	3	0	0	3
EE614	Digital Controllers in Power Electronics Applications	3	0	0	3
EE616	Computer Networking	3	0	0	3
EE618	Electrical Distribution Systems	3	0	0	3
EE620	Fuzzy Systems	3	0	0	3

Or any one course from other department

LIST OF RESERVE ELECTIVES

From year to year, the departmental electives listed under group 1 & group 2 elective subjects may be replaced by suitable courses from the following list depending upon the interest of the majority of the students.

CODE	COURSE OF STUDY	L	T	P	C
EE 621	Transient over voltages in Power Systems	3	0	0	3
EE622	Stochastic Models and Applications	3	0	0	3
EE623	Renewable Power Generation Sources	3	0	0	3
EE624	Power System Planning and Reliability	3	0	0	3
EE625	Advanced Power System Protection	3	0	0	3
EE626	Modeling and Analysis of Electrical Machines	3	0	0	3
EE627	Power Quality	3	0	0	3
EE628	Microcontrollers Applications in Power Converters	3	0	0	3
EE629	Power System Restructuring	3	0	0	3
EE630	Computer Relaying and wide area measurement systems	3	0	0	3
EE631	Architecture and programming of TMS320C6X DSK	3	0	0	3

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POWER SYSTEMS

MA603 - OPTIMIZATION TECHNIQUES

Linear programming –formulation-Graphical and simplex methods-Big-M method-Two phase method-Dual simplex method-Primal Dual problems.

Unconstrained one dimensional optimization techniques -Necessary and sufficient conditions –Unrestricted search methods-Fibonacci and golden section method-Quadratic Interpolation methods, cubic interpolation and direct root methods.

Unconstrained n dimensional optimization techniques – direct search methods –Random search –pattern search and Rosen brooch's hill claiming method- Descent methods-Steepest descent, conjugate gradient, quasi -Newton method.

Constrained optimization Techniques- Necessary and sufficient conditions –Equality and inequality constraints-Kuhn-Tucker conditions-Gradient projection method-cutting plane method- penalty function method .

Dynamic programming- principle of optimality- recursive equation approach-application to shortest route, cargo-loading, allocation and production schedule problems.

1. *Rao,S.S.,'Optimization :Theory and Application' Wiley Eastern Press, 2nd edition 1984.*
2. *Taha,H.A., Operations Research –An Introduction,Prentice Hall of India,2003.*
3. *Fox, R.L., 'Optimization methods for Engineering Design', Addition Welsey, 1971.*

EE601 - ADVANCED POWER SYSTEM ANALYSIS

Load Flow - Network modeling – Conditioning of Y Matrix – Load flow-Newton Raphson method- Decoupled – Fast decoupled Load flow -three-phase load flow.

DC power flow –Single phase and three phase -AC-DC load flow - DC system model – Sequential Solution Techniques – Extension to Multiple and Multi-terminal DC systems – DC convergence tolerance – Test System and results.

Fault Studies -Analysis of balanced and unbalanced three phase faults – fault calculations – Short circuit faults – open circuit faults.

System optimization - strategy for two generator systems – generalized strategies – effect of transmission losses - Sensitivity of the objective function- Formulation of optimal power flow-solution by Gradient method-Newton's method.

State Estimation – method of least squares – statistics – errors – estimates – test for bad data – structure and formation of Hessian matrix – power system state estimation.

1. *Grainger, J.J. and Stevenson, W.D. 'Power System Analysis' Tata McGraw hill, New Delhi, 2003.*
2. *Arrillaga, J and Arnold, C.P., 'Computer analysis of power systems' John Wiley and Sons, New York, 1997.*
3. *Pai, M.A., 'Computer Techniques in Power System Analysis', Tata McGraw hill, New Delhi, 2006.*

EE602 – POWER SYSTEM OPERATION AND CONTROL

Economic operation- Load forecasting - Unit commitment – Economic dispatch problem of thermal units – Gradient method-Newton's method –Base point and participation factor method.

Hydro-thermal co-ordination-Hydroelectric plant models –short term hydrothermal scheduling problem - gradient approach – Hydro units in series - pumped storage hydro plants-hydro-scheduling using Dynamic programming and linear programming.

Automatic generation control -Review of LFC and Economic Dispatch control (EDC) using the three modes of control viz. Flat frequency – tie-line control and tie-line bias control – AGC implementation – AGC features - static and dynamic response of controlled two area system

MVAR control - Application of voltage regulator – synchronous condenser – transformer taps – static VAR compensators

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

1. *Allen J.Wood and Wollenberg B.F., 'Power Generation Operation and control', John Wiley & Sons, Second Edition,1996.*
2. *Kirchmayer L.K., 'Economic Control of Interconnected Systems', John Wiley & Sons, 1959.*
3. *Nagrath, I.J. and Kothari D.P., 'Modern Power System Analysis', TMH, New Delhi, 2006.*

EE603 – POWER CONVERSION TECHNIQUES

DC-DC converters-Buck converter, boost converter, buck-boost converter, averaged circuit modeling, input-output equations, ripple calculations, filter design

DC-AC inverters -Single phase VSI, Three phase VSI, Single phase CSI, Three phase CSI, voltage control and harmonic reduction in inverters-standard PWM techniques.

AC-DC converters- Uncontrolled (Diode rectifier), single and three phase fully controlled (SCR-line commutated) and semicontrolled converters, continuous current conduction, discontinuous current conduction, Reactive compensation, Harmonic compensation techniques.

AC-AC converters-single phase and three phase circuits employing Phase angle control, on-off control. AC choppers.

Loss calculations and thermal management: Device models for loss calculations, ratings, safe operating areas, data sheets, forward conduction loss, switching losses, heat sink design, snubber design drive and protection circuits, commutation circuits, Soft switching.

1. *Ned Mohan, Undeland and Robbin, 'Power Electronics: converters, Application and design', John Wiley and sons.Inc, Newyork, 3rd edition,2002.*

2. *Rashid M.H., 'Power Electronics Circuits, Devices and Applications', Prentice Hall India,New Delhi, 3rd edition ,2004.*

3. *N.G.Hingorani and L.G.Gyugyi 'Understanding FACTS', IEEE press, New York, 2000 ISBN –078033 4588., 1998.*

EE604 – HIGH VOLTAGE DC TRANSMISSION

General aspects -HVAC and HVDC links –comparison – economic, technical performance reliability-limitation-properties of thyristor converter circuits -choice of best circuit for HVDC converters, types of HVDC links-monopolar, bipolar&homopolar links.

Thyristor converter circuits -Analysis with and without overlap in converters - basic means of control- inverter operation of converters-power reversal-desired features of control-actual control characteristics

Basic methods of control-constant ignition angle control, Constant current control and constant extinction advance angle control – power control – high level controllers. Converter faults-misfire, arc through, commutation failure-D.C. Reactors-voltage and current oscillations-Circuit breakers, over voltage and over current protection.

Characteristic and uncharacteristic harmonics-troubles due to harmonics-harmonic filters-active and passive filters. Reactive power control of converters.

Interaction between ac and dc systems- converter transformers-earth electrodes-Basics of VSC based HVDC transmission systems-Introduction to multiterminal HVDC systems and Hybrid HVDC systems - design of back to back thyristor converter system.

1. *Padiyar, K.R., 'HVDC transmission systems', Wiley Eastern Ltd., New Delhi, 2010.*
2. *Kimbark, E.W., 'Direct current transmission-vol.1', Wiley Interscience, New York, 1971.*
3. *Arrilaga, J., 'High voltage direct current transmission', peter pereginver Ltd., London, U.K.1983.*

EE605 POWER SYSTEM STABILITY

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.

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.

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.

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.

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.

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, 1994.*
3. *Van Cutsem, T. and Vournas, C., 'Voltage Stability of Electric Power Systems', Kluwer Academic Publishers, 1998.*

EE606 - FLEXIBLE AC TRANSMISSION SYSTEMS

Fundamentals of ac power transmission, transmission problems and needs, emergence of FACTS-FACTS control considerations, FACTS controllers.

Principles of shunt compensation – Variable Impedance type & switching converter type- Static Synchronous Compensator (STATCOM) configuration, characteristics and control.

Principles of static series compensation using GCSC, TCSC and TSSC, applications, Static Synchronous Series Compensator (SSSC).

Principles of operation-Steady state model and characteristics of a static voltage regulators and phase shifters- power circuit configurations.

UPFC -Principles of operation and characteristics, independent active and reactive power flow control, comparison of UPFC with the controlled series compensators and phase shifters.

1. *Song, Y.H. and Allan T. Johns, 'Flexible ac transmission systems (FACTS)', Institution of Electrical Engineers Press, London, 1999.*
2. *Hingorani ,L.Gyugyi, ' Concepts and Technology of flexible ac transmission system', IEEE Press New York, 2000 ISBN – 078033 4588.*
3. *R .Mohan Mathur and Rajiv K.Varma , 'Thyristor - based FACTS controllers for Electrical transmission systems', IEEE press, Wiley Inter science , ISBN no . 0-471-20643-1,2002.*
4. *K.R.Padiyar, 'FACTS controllers for transmission and Distribution systems' New Age international Publishers 1st edition - 2007.*

EE608 - POWER SYSTEM SIMULATION LABORATORY

1. Load flow studies.
2. Short circuit studies.
3. Transient stability studies.
4. Simulation of IGBT inverters.
5. Simulation of thyristor converters.
6. Economic Load Dispatch with thermal power plants.
7. Economic Load Dispatch with Hydro thermal power plants.
8. Simulation of Facts controllers
9. Simulation of single -area and Two -area Systems.
10. Load forecasting and unit commitment.

Software ETAP/ MiPOWER / MATLAB / LABVIEW will be used.

ELECTIVES

EE611 – INDUSTRIAL CONTROL ELECTRONICS

Review of switching regulators and switch mode power supplies-Uninterrupted power supplies- OFF-LINE AND ON-LINE TOPOLOGIES-Analysis of UPS topologies-solid state circuit breakers-solid-state tap-changing of transformer

Analog Controllers - Proportional controllers, Proportional – Integral controllers, PID controllers, derivative overrun, integral windup-cascaded control-Feedforward control-Digital control schemes- control algorithms-programmable logic controllers

Signal conditioners-Instrumentation amplifiers – voltage to current, current to voltage, voltage to frequency, frequency to voltage converters ; Isolation circuits – cabling; magnetic and electro static shielding and grounding.

Opto-Electronic devices and control , electronic circuits for photo-electric switches-output signals for photo-electric controls; Applications of opto-isolation, interrupter modules and photo sensors – Fiber optics – Bar code equipment, application of barcode in industry.

Stepper motors – types, operation, control and applications; servo motors- types, operation, control and applications – servo motor controllers – servo amplifiers – linear motor applications-selection of servo motor.

1. Michael Jacob, 'Industrial Control Electronics – Applications and Design', Prentice Hall, 1988.

2. Thomas, E. Kissel, ' Industrial Electronics'PHI, 2003

3. James Maas, 'Industrial Electronics', Prentice Hall, 1995.

EE612 - POWER ELECTRONIC DRIVES

Basic power electronic drive system, components. Different types of loads, shaft-load coupling systems. Stability of power electronic drive.

Conventional methods of DC motor speed control, single phase and three phase converter fed D.C motor drive. Power factor improvement techniques, four quadrant operation.

Chopper fed drives, input filter design. Step-up chopper for photovoltaic systems. Braking and speed reversal of DC motor drives using choppers, multiphase choppers.

Conventional methods of induction motor speed control.. Solid state controllers for Stator voltage control, soft starting of induction motors, Rotor side speed control of wound rotor induction motors. Voltage source and Current source inverter fed induction motor drives.

Speed control of synchronous motors, field oriented control, load commutated inverter drives, switched reluctance motors and permanent magnet motor drives.

1. *P.C Sen, 'Thyristor DC Drives', John wiely and sons, New York, 1981.*
2. *R.Krishnan, 'Electric Motor Drives – Modeling, Analysis and Control', Prentice-Hall of India Pvt Ltd., New Delhi, 2003.*
3. *Bimal K.Bose, 'Modern Power Electronics and AC Drives', Pearson Education (Singapore) Pte. Ltd., New Delhi, 2003.*

EE613- SYSTEM THEORY

Introduction to state space modeling, modeling of physical systems. Solution to vector differential equations and state transition matrix.

Controllability and Observability definitions and Kalman rank conditions. Detectability and Stabilizability, Kalman decomposition.

Introduction to nonlinear systems. Phase plane analysis of nonlinear system using linear approximation. Limit cycle and periodic solutions. Singular points (equilibrium points) and qualitative behavior near singular points.

Stability of nonlinear systems. Lyapunov direct and indirect methods. Input to state stability. Various methods to check the stability of nonlinear systems.

State feedback controller design using pole placement. Observer design using Kalman filter algorithm. LQR and LQG controller design.

1. *Ogata, K., 'Modern Control Engineering', Prentice Hall of India, 1981.*
2. *C.T. Chen*, '*Linear Systems* Theory and Design'' Oxford University Press, 3rd Edition, 1999.
3. M. *Vidyasagar*, '*Nonlinear Systems* Analysis', 2nd edition, Prentice Hall, Englewood Cliffs, New Jersey 07632.
4. Hassan K. *Khalil, Nonlinear Systems* (3rd Edition), Pearson Educational International Inc. Upper Saddle River, New Jersy 07458

EE614 DIGITAL CONTROLLERS IN POWER ELECTRONICS APPLICATIONS

Introduction to the C2xx DSP core and code generation, The components of the C2xx DSP core, Mapping external devices to the C2xx core , peripherals and Peripheral Interface , System configuration registers , Memory , Types of Physical Memory , memory Addressing Modes , Assembly Programming using C2xx DSP, Instruction Set, Software Tools.

Pin Multiplexing (MUX) and General Purpose I/O Overview, Multiplexing and General Purpose I/O Control Registers .Introduction to Interrupts , Interrupt Hierarchy , Interrupt Control Registers , Initializing and Servicing Interrupts in Software .

ADC Overview , Operation of the ADC in the DSP , Overview of the Event manager (EV) , Event Manager Interrupts , General Purpose (GP) Timers , Compare Units, Capture Units And Quadrature Enclosed Pulse (QEP) Circuitry , General Event Manager Information

Introduction to Field Programmable Gate Arrays – CPLD Vs FPGA – Types of FPGA , Xilinx XC3000 series , Configurable logic Blocks (CLB), Input/Output Block (IOB) – Programmable Interconnect Point (PIP) – Xilinx 4000 series – HDL programming –overview of Spartan 3E and Virtex II pro FPGA boards- case study.

Controlled Rectifier , Switched Mode Power Converters , PWM Inverters , DC motor control , Induction Motor Control

1. *Hamid.A.Toliyat and Steven G.Campbell " DSP Based Electro Mechanical Motion Control " CRC Press New York , 2004*
2. *XC 3000 series datasheets (version 3.1). Xilinx,Inc.,USA, 1998*
3. *XC 4000 series datasheets (version 1.6). Xilinx,Inc.,USA, 1999*
4. *Wayne Wolf," FPGA based system design ", Prentice hall, 2004*

EE615 ANALYSIS AND DESIGN OF ARTIFICIAL NEURAL NETWORKS

Pattern classification –Learning and generalisation-structure of neural networks – ADA line and Mada line-perceptrons.

Linear separability – Back propagation – XOR function-Backpropagation algorithm-Hopfied and Hamming networks-Kohensen's network-Boltzmenn machine-in and out star network – Art 1 and Art 2 nets.

Neuro adaptive control applications-ART architecture – Comparision layer – Recognition layer – ART classification process – ART implementation – Examples.

Character recognition networks, Neural network control application, connectionist expert systems for medical diagnosis, Self organizing maps.

Applications of neural algorithms and systems -Character recognition networks, Neural network control application, connectionist expert systems for medical diagnosis.

1. *Martin T. Hogan , Howard B.Demuth. M,'Neural network design'4th edition*
2. *Zureda, J.M.,'Introduction to Artificial Neural Systems', Jaico publishing house, Bombay, 1994.*
3. *Zimmermann, H.J.,' Fuzzy set theory and its applications', Allied publishers limited,Madras, 2000.*

EE616 COMPUTER NETWORKING

Computer Network – Hardware and Software, OSI and TCP reference Model, Transmission media, Wireless transmission, public switched telephone network - Structure, multiplexing and switching.

Data link layer - design issues, Data link protocols. Medium access sub layer - channel allocations, Multiple Access protocols, IEEE protocols.

Network layer - Design issues, routing algorithms, congestion control algorithms, QoS, Transport layer- Design issues, Connection management .

Application layer – DNs, Electronic mail, World Wide Web, multimedia, Cryptography,

Internet transport protocols - TCP and UDP

1. *James F. Kurose and Keith W. Ross, 'Computer Networking', 2nd Edition, Pearson Education, 2003.*

2. *Tanenbaum, A.S., 'Computer Networks', 4th Edition, Prentice Hall of India, 2003.*

3. *Stallings, W., 'Data and Computer Communication',PHI,8th edition, 2006.*

EE617 DIGITAL SIGNAL PROCESSING & APPLICATIONS

Discrete-Time Signals- Shanon's sampling theorem- Difference equation description- characteristics of digital filters and time domain analysis- properties of discrete time system (linearity, time-variance, convolution)- BIBO stability- Z-transformation and their application in solving difference equations- Relationship between Laplace and Z-transforms.

Discrete Time Fourier Transform (DTFT) and Discrete Fourier Transform (DFT)- Periodic convolution- Direct evaluation of DFT, FFT algorithms decimation in time and frequency, Relationship between Fourier and Z-transforms.

Direct form I&II- cascade- parallel and ladder realizations. Filter Function Approximations and Transformations-Review of approximations of ideal analog filter response- Butterworth filter- Chebyshev Type I & II-Frequency transformation in analog domain- frequency transformation in digital domain.

Design based on analog filter approximations- Impulse invariance Method- Matched Z-transformation-Bilinear transformation-comparison of FIR and IIR filters.

Symmetric and antisymmetric FIR filters- design of linear phase FIR filters using windows and frequency – sampling methods-design of optimum equiripple linear phase FIR filters. Introduction to Multirate signal processing-Introduction to STFT and WT.

1. *John G. Proakis, Dimitris G. Mamalakis, Digital Signal Processing, Principles, Algorithms and Applications,PHI India,2006.*
2. *Alan V. Oppenheim Ronald W. Schafer, Digital Signal Processing, PHI, India,2002.*
3. *Antonious, Digital Filter Design, Tata Mc-Graw-Hill ,1999.*
4. *Sanjit K.Mitra, "Digital Signal Processing: A Computer – Based Approach", Tata McGraw-Hill, 2001, Second Edition.*

EE618- ELECTRICAL DISTRIBUTION SYSTEMS

Industrial and commercial distribution systems – Energy losses in distribution system – system ground for safety and protection – comparison of O/H lines and under ground cable system .Network model – power flow, short circuit and loss calculations.

Distribution system, reliability analysis – reliability concepts – Markov model – distribution network reliability – reliability performance-

Distribution system expansion -planning – load characteristics – load forecasting – design concepts – optimal location of sub station – design of radial lines – solution technique.

Voltage control – Application of shunt capacitance for loss reduction – Harmonics in the system – static VAR systems –loss reduction and voltage improvement.

System protection – requirement – fuses and section analyzers-over current. Under voltage and under frequency protection – coordination of protective device.

1. *Pabla, A.S., 'Electrical Power Distribution System', 5th edition,Tata McGraw hill, 2004.*
2. *Tuvar Goner, 'Electrical Power Distribution System Engineering', McGraw hill, 1986.*
3. *Sterling, M.I.H., 'Power System Control', Peter Peergisus, 1979.*

EE619 - DIGITAL SYSTEM DESIGN

Review of sequential circuits, Mealy & Moore Models, Analysis & Synthesis of Synchronous sequential circuits

Digital system design Hierachy, ASM charts, Hardware description language, Control logic Design Reduction of state tables, State Assignments.

Analysis and synthesis of Asynchronous sequential circuits, critical and non-critical races, Essential Hazard

Combinational and sequential circuit design with PLD's , Introduction to CPLD's & FPGA's.

Fault classes and models – Stuck at faults, Bridging faults, Transition and Intermittent faults. Fault Diagnosis of combination circuits by conventional methods- Path sensitization technique, Boolean different method and Kohavi algorithm.

1. *Digital principles and design – Donald D.Givone*
2. *Digital Design – Morris Mano- 3rd Edition, PHI*
3. *Digital circuits and logic design – Samuel C.Lee, PHI.*
4. *.Logic Design Theory – N.N.Biswas, PHI.*
5. *Switching and Finite Automata Theory – Kohavi ZVI, 2nd Edition, TMH.*

EE620 - FUZZY SYSTEMS

Different faces of imprecision – inexactness, Ambiguity, Undecidability, Fuzziness and certainty, Probability and fuzzy logic, Intelligent systems.

Fuzzy sets and crisp sets - Intersections of Fuzzy sets, Union of Fuzzy sets, the complement of Fuzzy sets

Fuzzy reasoning - Linguistic variables, Fuzzy propositions, Fuzzy compositional rules of inference- Methods of decompositions, defuzzification

Methodology of fuzzy design - Direct & Indirect methods with single and multiple experts, Adaptive fuzzy control, Rule base design using dynamic response.

Fuzzy logic applications to engineering, Fuzzy decision making, Neuro-Fuzzy systems, Fuzzy Genetic Algorithms.

1. *Zimmermann, H.J., 'Fuzzy set theory and its applications', Allied publishers limited, Madras,1996.*
2. *Klir, G.J., and Folger. T., 'Fuzzy sets, uncertainty and information', PHI, New Delhi,1997.*
3. *EarlCox,'The Fuzzy Systems Handbook', AP professional Cambridge,1998. MA 02139, 1994.*

RESERVE ELECTIVES

EE621 - TRANSIENT OVER VOLTAGES IN POWER SYSTEMS

Transients in electric power systems – Internal and external causes of over voltages-– Lightning strokes – Mathematical model to represent lightning,Travelling waves in transmission lines – Circuits with distributed constants – Wave equations – Reflection and refraction of travelling waves – Travelling waves at different line terminations.

Switching transients –double frequency transients – abnormal switching transients – Transients in switching a three phase reactor-three phase capacitor.

voltage distribution in transformer winding – voltage surges-transformers –generators and motors, Transient parameter values for transformers,reactors,generators and transmission lines.

Basic ideas about protection –surge diverters-surge absorbers-protection of lines and stations Modern lighting arrestors,Insulation coordination,Protection of alternators and industrial drive systems.

Generation of high AC and DC-impulse voltages,currents-measurement using sphere gaps-peak vpltmeters-potential dividers and CRO.

1. *Allen Greenwood, 'Electrical transients in power systems', Wiley Interscience, 1991.*
2. *Bewley, L.W., 'Travelling waves and transmission systems', Dover publications, New York, 1963.*
3. *Gallaghar, P.J. and Pearmain, A.J., 'High voltage measurement, Testing and Design', John Wiley and sons, New York, 2001.*

EE622- STOCHASTIC MODELS AND APPLICATIONS

Probability Spaces- Discrete probability distributions, Continuous probability densities, Conditional probability, distribution and densities. Distribution functions, Multiple random variables and joint distributions.

Expectations, moments, Characteristic functions and moments generating functions, sequence of random variables and Convergence Concepts.

Law of large numbers – Discrete and continuous random variables; Central limit theorem – Bernoulli trials, Discrete and continuous independent trials.

Stochastic processes-Markov chains – Transient analysis, Computation of equilibrium probabilities, Stationary distribution and Transient distribution of markov chains.

Poisson processes – Exponential distribution and applications; Birth-death processes and applications.

1. *Hole, P.G., Port, S.C., and Stone,C.J.,' Introduction to Probability Theory', Indian Edition Universal Book Stall, New Delhi,1998.*
2. *Hole,P.G., Port, S.C., and Stone,C.J.,' Introduction to Stochastic Process', Indian Edition Universal Book Stall, New Delhi,2008.*

EE623 - RENEWABLE POWER GENERATION SOURCES

Basic characteristics of sunlight – solar energy resource – photovoltaic cell-characteristics – equivalent circuit – photo voltaic for battery charging.

Wind source – wind statistics - energy in the wind – aerodynamics - rotor types – forces developed by blades-Aerodynamic models – braking systems – tower - control and monitoring system – power performance

Wind driven induction generators-power circle diagram-steady state performance –modeling-integration issues –impact on central generation- transmission and distribution systems – wind farm electrical design.

Wind-diesel systems-fuel savings-permanent magnet alternators – modeling – steady state equivalent circuit-self-excited induction generators – integrated wind-solar systems.

Micro-hydel electric systems – power potential – scheme layout – generation efficiency and turbine part flow-isolated and parallel operation of generators – geothermal-tidal and OTEC systems.

1. *John F.Walker & Jenkins. N , 'Wind energy Technology ' , John Wiley and sons, chichester , U.K ,1997.*
2. *Van Overstraeton and Mertens R.P., 'Physics, Technology and use of Photovoltaics', Adam Hilger, Bristol,1996.*
3. *Freries LL , ' Wind Energy Conversion Systems', Prentice Hall, U.K., 1990*

EE624 – POWER SYSTEM PLANNING AND RELIABILITY

Objectives of planning – Long and short term planning .Load forecasting – characteristics of loads – methodology of forecasting – energy forecasting – peak demand forecasting – total forecasting – annual and monthly peak demand forecasting.

Reliability concepts – exponential distributions – meantime to failure – series and parallel system – MARKOV process – recursive technique.Generator system reliability analysis – probability models for generators unit and loads – reliability analysis of isolated and interconnected system – generator system cost analysis – corporate model – energy transfer and off peak loading.

Transmission system reliability model analysis –average interruption rate-LOLP method-frequency and duration method.

Two plant single load system-two plant two load system-load forecasting uncertainly interconnections benefits.

Introduction to system modes of failure – the loss of load approach – frequency & duration approach – spare value assessment – multiple bridge equivalents.

1. *Sullivan, R.L., 'Power System Planning', Heber Hill, 1987.*
2. *Roy Billington, 'Power System Reliability Evaluation', Gordan & Breach Scain Publishers, 1990.*
3. *Eodrenyi, J., 'Reliability modelling in Electric Power System' John Wiley, 1980.*

EE625- ADVANCED POWER SYSTEM PROTECTION

General philosophy of protection-Classification and Characteristic function of various protective relays-basic relay elements and relay terminology-Development of relaying scheme.

Protection of power system apparatus –protection of generators – Transformer protection – magnetizing inrush current – Application and connection of transformer differential relays – transformer over current protection.

Bus bar protection, line protection, distance protection–long EHV line protection, Power line carrier protection.

Reactor protection–Protection of boosters-capacitors in an interconnected power system.

Digital signal processing –digital filtering in protection relays- numeric protection –testing digital filtering in protection relays – digital data transmission– relay hardware – relay algorithms.Concepts of modern coordinated control system.

1. *Lewis Blackburn, J., 'Protective Relaying – Principles and Applications', Marcel Dekkar, INC, New York, 2006.*
2. *The Electricity Training Association, 'Power System Protection Vol1-4', The IEE, U.K., 1995.*
3. *C. Russeil Mason, 'The art and Science of Protective Relaying', GE Publishers, 1962.*
4. *A. T. Johns and S. K. Salman, 'Digital Protection for Power Systems', Peter Peregrinus Ltd., 1997.*

EE626 -MODELING AND ANALYSIS OF ELECTRICAL MACHINES

Principles of Electromagnetic Energy Conversion, General expression of stored magnetic energy, co-energy and force/torque, example using single and doubly excited system.

Basic Concepts of Rotating Machines-Calculation of air gap mmf and per phase machine inductance using physical machine data; Voltage and torque equation of dc machine.

Three phase symmetrical induction machine and salient pole synchronous machines in phase variable form; Application of reference frame theory to three phase symmetrical induction and synchronous machines, dynamic direct and quadrature axis model in arbitrarily rotating reference frames

Determination of Synchronous Machine Dynamic Equivalent Circuit Parameters, Analysis and dynamic modeling of two phase asymmetrical induction machine and single phase induction machine.

Special Machines - Permanent magnet synchronous machine: Surface permanent magnet (square and sinusoidal back emf type) and interior permanent magnet machines. Construction and operating principle, dynamic modeling and self controlled operation; Analysis of Switch Reluctance Motors.

1. *Charles Kingsley,Jr., A.E. Fitzgerald, Stephen D.Umans, 'Electric Machinery', Tata Mcgraw Hill,6ht Edition, 2003.*
2. *R. Krishnan, 'Electric Motor & Drives: Modeling, Analysis and Control', Prentice Hall of India, 2001.*
3. *Miller, T.J.E,. 'Brushless permanent magnet and reluctance motor drives', Clarendon Press, Oxford, 1989.*

EE627 POWER QUALITY

Electric power quality phenomena- IEC and IEEE definitions - power quality disturbances- voltage fluctuations-transients-unbalance-waveform distortion-power frequency variations.

Voltage variations, Voltage sags and short interruptions – flicker-longer duration variations - sources – range and impact on sensitive circuits-standards – solutions and mitigations – equipment and techniques.

Transients – origin and classifications – capacitor switching transient – lightning-load switching – impact on users – protection – mitigation.

Harmonics – sources – definitions & standards – impacts - calculation and simulation – harmonic power flow - mitigation and control techniques – filtering – passive and active.

Power Quality conditioners – shunt and series compensators-DStatcom-Dynamic voltage restorer-unified power quality conditioners-case studies.

1 *Heydt, G.T., 'Electric Power Quality', Stars in a Circle Publications, Indiana,2nd edition 1994.*

2 *Bollen, M.H.J., 'Understanding Power Quality Problems: Voltage sags and interruptions', IEEE Press, New York, 2000.*

3 *Arrillaga, J, Watson, N.R., Chen, S., 'Power System Quality Assessment', Wiley, New York, 2000.*

EE628–MICRO CONTROLLERS APPLICATIONS IN POWER CONVERTERS

Use of microcontrollers for pulse generation in power converters-overview of zero crossing detectors-typical firing /gate – drive circuits-firing /gate pulses for typical single phase and three phase power converters –PIC16F876 microcontrollerdevice overview –pin diagrams.

PIC16F876 micro controller memory organization –special function registers-I/O ports –timers-capture/compare/PWM modules(CCP)

Analog to digital converter module-instruction set –instruction description –introduction to PIC microcontroller programming – oscillator selection –reset-interrupts-watch dog timer.

Introduction to MPLAB IDE and PICSTART plus –device programming using MPLAB and PICSTART plus –generation of firing/gating pulses for typical power converters.

8051 microcontroller-architecture –addressing modes-I/O ports-instruction sets-simpke assembly language programming.

1. *PIC16F87X datasheet 28/40-pin 8 bit CMOS flash microcontrollers, microchip technology Inc.,2001 and MPLAB IDE Quick start guide, Microchip Technology Inc.,2007.*

EE629 POWER SYSTEM RESTRUCTURING

Introduction – Market Models – Entities – Key issues in regulated and deregulated power markets; Electricity markets - California Market – New England ISO – Midwest ISO - Nordic Pool– Power market in China.

Operational and planning activities of a Genco - Electricity Pricing and Forecasting -Price Based Unit Commitment Design - Security Constrained Unit Commitment design. - Ancillary Services for Restructuring- Automatic Generation Control (AGC).

Introduction-Components of restructured system-Transmission pricing in Open-access system-Open transmission system operation; Congestion management in Open-access transmission systems- FACTS in congestion management - Open-access Coordination Strategies; Power Wheeling-Transmission Cost Allocation Methods

Open Access Distribution - Changes in Distribution Operations- The Development of Competition – Maintaining Distribution Planning

Power Market Development – Electricity Act, 2003 - Key issues and solution; Developing power exchanges suited to the Indian market - Challenges and synergies in the use of IT in power- Competition- Indian power market- Indian energy exchange- Indian power exchange- Infrastructure model for power exchanges- Congestion Management-Day Ahead Market- Online power trading.

1. *Loi Lei Lai, "Power System Restructuring and Deregulation", John Wiley & son LTD, New York, 2001.*
2. *Mohammad Shahidehpour, Hatim Yamin, "Market operations in Electric power systems", John Wiley & son LTD, Publication, 2002.*
3. *Lorrin Philipson, H. Lee Willis, "Understanding Electric Utilities and Deregulation" Taylor & Francis, New York 2006.*
4. *MohammadS hahidehpour, Muwaffaq Alomoush, "Restructured Electrical Power Systems", Marcel Dekker, INC., New York, 2001.*

EE630 COMPUTER RELAYING AND WIDE AREA MEASUREMENT SYSTEMS

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

Mathematical basis for protective relaying algorithms-Walsh functions- Fourier transforms- discrete fourier transform- Random processes- Filtering of random processes- Kalman filtering- Digital filters-Windows and windowing- Linear phase Approximation- filter synthesis- Wavelets- Elements of artificial intelligence.

Phasor Measurement Unit– Introduction- Phasor representation of sinusoids- Fourier series and Fourier transform and DFT Phasor representation- Phasor Estimation of Nominal Frequency-Signals- Formulas for updating phasors -Nonrecursive updates- Recursive updates- Frequency Estimation

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

Phasor Measurement Applications-State Estimation-History- Operator's load flow- weighted least square least square- Linear weighted least squares; Nonlinear weighted least squares- Static state estimation- State estimation with Phasors measurements- linear state estimation. Adaptive protection- Differential and distance protection of transmission lines- Adaptive protection- Adaptive out-of-step protection.

1. *Arun G. Phadke, James S. Thorp, 'Computer Relaying for Power Systems'- A John Wiley and Sons Ltd.- Research Studies Press Limited-2009*

EE631 ADVANCED DSP ARCHITECTURE AND PROGRAMMING FOR TMS320C6X DSK

DSP Development system: Introduction to DSP- Example of DSP system A to D signal conversion- DSP Support tools- code composer studio- compiler- assembler and linker- input and output with the DSK

Architecture of C6x Processor: Introduction TMS321 C6x architecture- functional units- fetch and execute packets- pipe lining- registers- Liner and circular addressing modes

Instruction of C6x Processor: Instruction set assembly directives- liner assembly- ASM statement within C- timers- interrupts- multi channel buffering serial ports- direct memory access- memory consideration- fixed and floating points format- code improvement and constraints. Fast Fourier Transform: Introduction- DIT FFT algorithm with Radix 2- DIF FFT algorithm with Radix 2- inverse fast Fourier transform- fast convolution- programming example using C language

Real Time FIR Filtering: Design of FIR filter- FIR lattice structure- FIR implementation using Fourier series- windows function- programming examples using C language. Real Time IIR Filtering: Design of IIR filter- IIR lattice structure- impulse invariance- bilinear transformation programming examples using C language.

DSP/BIOS and RTDX using MATLAB & Lab View: Introduction to DSP/BIOS- RTDX using MATLAB provide interface between PC and DSK- RTDX using Lab VIEW provide interface between PC and DSK.

1. *Digital signal processing and applications C6713 and C6416 DSK by Rulph Chassaing- Wiely publication,2005.*
2. *Real-Time digital signal processing based on the TMS320C6000 by Nasser Kehtarnavaz- ELSEVIER publication,2004.*
3. *DSP applications using C and the TMS320c6x DSK by Rulph Chassaing- Wiely publication,2002.*