M.Tech. Programme

in

POWER ELECTRONICS

SYLLABUS

FOR

CREDIT BASED CURRICULUM

(Applicable for 2008 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 Electronics is 64.

SEMESTER - I

CODE	COURSE OF STUDY	L	T	P	C
MA603	Optimization Techniques	3	0	0	3
EE651	Power Converters	3	0	0	3
EE653	Industrial Control Electronics	3	0	0	3
EE655	System Theory	3	0	0	3
	Elective I	3	0	0	3
	Elective II	3	0	0	3
EE657	Power Converters Laboratory	0	0	3	2
	Total	18	0	3	20

SEMESTER -II

CODE	COURSE OF STUDY	L	T	P	C
EE652	Switched Mode Power Conversion	3	0	0	3
EE654	Power Electronic Drives	3	0	0	3
EE656	Microcontroller applications in power converters	3	0	0	3
	Elective III	3	0	0	3
	Elective IV	3	0	0	3
	Elective V	3	0	0	3
EE658	Power modules laboratory	0	0	3	2
	Total	18	0	3	20

SEMESTER -III

CODE	COURSE OF STUDY	L	T	P	C
EE697	Project Work	0	0	24	12

SEMESTER – IV

CODE	COURSE OF STUDY	L	T	P	C
EE698	Project Work	0	0	24	12

For the elective courses, a student may take a maximum of two courses from other departments.

ELECTIVES

CODE	COURSE OF STUDY	L	T	P	C
Group I elective subjects recommended for 1st semester					
EE601	Advanced Power System Analysis	3	0	0	3
EE615[G]	Analysis and Design of Artificial Neural Networks	3	0	0	3
EE627	Digital Signal Processing and Applications	3	0	0	3
EC661	Digital System Design	3	0	0	3
	Any One course from other department				
Group II elective subjects recommended for 2nd semester					
EE606	Flexible AC Transmission Systems	3	0	0	3
EE616[G]	Computer Networking	3	0	0	3
EE624	Fuzzy Systems	3	0	0	3
EE626	Digital Controllers in Power Electronics Applications	3	0	0	3
IC662	Design of Intelligent Controllers	3	0	0	3
IC668	VLSI Architecture and Design Methodologies	3	0	0	3
	Or any one course from other departments.				

G-Global Elective

LIST OF RESERVE ELECTIVES

From year to year the departmental electives subjects listed under group I and group II above may be replaced by suitable courses from the following list depending up on the interest of the majority of the students.

EE602	Power System Operation and Control	3	0	0	3
EE604	High Voltage DC Transmission	3	0	0	3
EE614	Transient over voltages in power systems	3	0	0	3
EE618	Electrical Distribution Systems	3	0	0	3
EE619	Stochastic Models and Applications	3	0	0	3
EE620	Renewable Power Generation Sources	3	0	0	3
EE621	Power System Planning and Reliability	3	0	0	3
EE622	Advanced Power System Protection	3	0	0	3
EE623	Modeling and Analysis of Electrical Machines	3	0	0	3
EE672	Digital Simulation of Power Electronic Systems	3	0	0	3
EE674	PWM Converters and Applications	3	0	0	3

MA603-OPTIMIZATIONTECHNIQUES

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.*

EE651–POWERCONVERTERS

Analysis of switched circuits- thyristor controlled half wave rectifier – R, L, RL, RC load circuits, classification and analysis of commutation

Single-Phase and Three-Phase AC to DC converters- half controlled configurations-operating domains of three phase full converters and semi-converters – Reactive power considerations.

Analysis and design of DC to DC converters- Control of DC-DC converters, Buck converters, Boost converters, Buck-Boost converters, Cuk converters

Single phase and Three phase inverters, Voltage source and Current source inverters, Voltage control and harmonic minimization in inverters.

AC to AC power conversion using voltage regulators, choppers and cyclo-converters, consideration of harmonics.

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. *P.C Sen.,' Modern Power Electronics ', Wheeler publishing Co, First Edition, New Delhi, 1998.*

EE652–SWITCHEDMODEPOWERCONVERSION

Reactive Elements in Power Electronic Systems, Design of inductor, Design of transformer, Capacitors for power electronic applications.

Basic concepts of Switched Mode power converters, DC-DC converters Characteristics, constituent elements, operating principles.

Steady state analysis, stress and sizing of elements, control methods, duty ratio, current programmed, frequency programmed and sliding mode control, Dynamic analysis and frequency domain models.

Classification of resonant converters, Basic resonant circuit concepts, Load resonant converters, Resonant switch converters, Zero voltage switching.

Design of feed back compensators, unity power factor rectifiers, resistor emulation principle and applications to rectifiers.

1. *Switched Mode Power Conversion, Course Notes, CCE, IISc, 2004.*
2. *Issa Batarseh, 'Power Electronic Circuits', John Wiley, 2004.*
3. *Philip T Krein,' Elements of Power Electronics ',Oxford Press,1997.*

EE653–INDUSTRIAL CONTROL ELECTRONICS

Review of switching regulators and switch mode power supplies-Uninterrupted power supplies- solid state circuit breakers – programmable logic controllers

Analog Controllers - Proportional controllers, Proportional – Integral controllers, PID controllers, Feed forward control

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 , Applications of opto isolation, interrupter modules and photo sensors – Fibre optics – Bar code equipment, application of barcode in industry.

Stepper motors and servo motors- control and applications. Servo motors – servo motor controllers – servo amplifiers – selection of servo motor – applications of servo motors.

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.

EE654-POWERELECTRONICDRIVES

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

Conventional methods of D.C.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.*

EE655-SYSTEMTHEORY

State space modeling of physical systems – determining of STM – controllability and observability of time invariant linear system.

Different techniques of linearising non-linear systems – Describing functions for various types of non-linearities – describing function analysis of non linear control systems.

Method of constructing phase – trajectories- phase plane analysis of linear and non-linear systems – Bang-bang system.

Different methods of constructing Liapunov functions for linear and non-linear continuous systems – stability analysis.

Pole placement technique by state feedback for linear SISO time, invariant system – Theory of high-gain feedback-advantages – Pole placement technique along with high-gain feedback control.

1. *Gopal, M., 'Modern Control Systems Theory', Wiley Eastern Ltd., 1990.*
2. *Ogata, K., 'Modern Control Engineering', Prentice Hall of India, 4th edition, 2003.*
3. *Kuo, B.C., 'Automatic Control Systems', Prentice Hall of India, 1999.*

EE656–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 Micro-controller – device 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 – simple 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.

2. John B. Peatman, "Design with PIC Microcontrollers", Prentice Hall, 2003.

3. Myke Predko, "Programming and customising the PIC microcntroller", Third Edition, Tata McGraw Hill, 2008.

4. M.A. Mazidi, J.G Mazidi and R.D McKinlay, "The 8051 microcontroller and embedded systems", Second Edition, PHI, New Delhi, 2007.

EE657–POWERCONVERTERSLABORATORY

Experiments and computer simulations on:

Single phase, three phase Semi converters and Full converters,

DC-DC Choppers using SCRs and Self communicating Devices.

Single phase and three phase inverters using IGBTs,

AC-AC voltage regulators.

DC and AC drives

EE658-POWERMODULESLABORATORY

Development of various configurations of power modules using SCRs, IGBTs, power transistors and power MOSFETs. Practical converter design considerations- Snubber design, gate and base drive circuits.

DC to DC converters of various configurations using SCRs, IGBTs, power transistors and power MOSFETs.

DC to AC converters of various configurations using SCRs, IGBTs, power transistors and power MOSFETs.

AC to AC converters of various configurations using SCRs, IGBTs, power transistors and power MOSFETs..

Practical implementation of control techniques for voltage control, speed control and harmonic minimization.

1. *Ned Mohan, Undeland and Robbin, 'Power Electronics: converters, Application and design', John Wileyand sons.Inc, Newyork, 2002.*
2. *M.H. Rashid, 'Power Electronics Handbook', Elseiver Press, 2003.*
3. *John D. Lenk ,'Simplified Design of Switching Power Supplies', Butterworth-Heinemann, 1996.*

ELECTIVES

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 or 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 system – 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 SYSTEMS OPERATION AND CONTROL

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

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.

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 Operation of Power System', John Wiley & Sons, 1959.*
3. *Kirchmayer L.K., 'Economic Control of Interconnected Systems', John Wiley & Sons, 1989.*

EE604–HIGHVOLTAGEDCTRANSMISSION

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

Thyristor converter circuits -Analysis with overlap in converters - basic means of control-power reversal-desired features of control-actual control characteristics

Inverters- power control – commutation failure -D.C Reactors –voltage and current oscillations- Circuit breakers, over voltage protection

Characteristic and uncharacteristic harmonics-troubles due to harmonics-harmonic filters-converter charts of direct current and voltage-active and reactive power.

Interaction between ac and dc systems- converter transformers-earth electrodes-design of back to back thyristor converter system.

1. *Kimbark, E.W., 'Direct current transmission-vol.1', Wiley Interscience, New York, 1971.*
2. *Arrilaga, J., 'High voltage direct current transmission', peter pereginver Ltd., London,U.K.1998.*
3. *Padiyar, K.R., 'HVDC transmission systems', Wiley Eastern Ltd., New Delhi, 1992.*

EE606–FLEXIBLEACTRANSMISSIONSYSTEMS

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. John, 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. *IEE Tutorials on 'Flexible ac transmission systems', published in Power Engineering Journal, IEE Press, 1995.*
4. *K.R.Padiyar, 'FACTS controllers for transmission and Distribution systems' New Age international Publishers 1st edition -2007*

EE614-TRANSIENTOVERVOLTAGESINPOWERSYSTEMS

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- generation of high AC and DC –impulse voltages, currents- measurement .

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

1. *Allen Greenwood, 'Electrical transients in power systems', Wiley Interscience, 1991.*
2. *Bewley, L.W., 'Traveling 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.*

EE615^{G}–ANALYSISANDDESIGNOFARTIFICIALNEURAL NETWORKS

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

Linear separability – Back propagation – XOR function-Back propagation 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 – Comparison 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,1996.*
2. *Zuroda, 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^{G}–COMPUTERNETWORKING

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,5th edition, 2000.

EE618-ELECTRICALDISTRIBUTIONSYSTEMS

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', 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-STOCHASTICMODELSANDAPPLICATIONS

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.*

EE620-RENEWABLEPOWERGENERATIONSOURCES

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.*

EE621–POWERSYSTEMPLANNINGANDRELIABILITY

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

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 interconnection benefits.

Introduction – 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, 1996.*
3. *Dhillan, B.S., 'Power System Reliability, Safety and Management', An Arbor Sam, 1983.*

EE622-ADVANCEDPOWERSYSTEMPROTECTION

General philosophy of protection-Characteristic function of protective relays-basic relay elements and relay terminology-basic construction of static relays-non-critical switching circuits.

Protective relays –protection of generators – Transformer protection – magnetizing inrush current – Application and connection of transformer differential relays – transformer over current protection.

Bus protection, Techniques applicable for line protection –long EHV line protection Backup remote local and Breaker failure

Placement of reactors in power system- Transformer tap changing –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, CRC, New York, 2006.*
2. *The Electricity Training Association, 'Power System Protection Vol1-4', The IEE, U.K., 1995.*
3. *Stanley, H.Horowitz (ED), 'Protective relaying for power systems II', IEEE Press, 1992.*

EE623-MODELINGANDANALYSISOFELECTRICALMACHINES

Priniples 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, Fifth Edition, 1992.*
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 ress, Oxford, 1989.*

EE624-FUZZYSYSTEMS

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,2001*
2. *Klir, G.J., and Folge., T., 'Fuzzy sets, uncertainty and information', PHI, New Delhi, 1997.*
3. *EarlCox,,'The Fuzzy Systems Handbook', AP professional Cambridge, MA 02139, 1998.*

EE626DIGITALCONTROLLERSINPOWERELECTRONICS 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 .*

EE627DIGITALSIGNALPROCESSING&APPLICATIONS

Review of Discrete – Time Signal & System representation in Z – Transform domain – Inverse Z – Transform – Properties – System characterization in Z – domain -- Equivalence between Fourier Transform and the Z-Transform of a Discrete signal.

Sampling in Fourier domain - Discrete Fourier Transform and its properties – Linear filtering using DFT – Resolution of DFT - FFT Algorithm – Radix-2 FFT Algorithm - DIT & DIF Structures - Higher Radix schemes.

Classification of filter design - Design of IIR filters – Bilinear transformation technique – Impulse invariance method – Step invariance method.

FIR filter design – Fourier series method - Window function technique - Finite Word Length Effects.

Introduction to Multirate Signal Processing - Decimation - Interpolation - Case Studies on Speech Coding, Transform Coding – DSP based measurement system.

1. *Ludemann L. C., "Fundamentals of Digital Signal Processing", Harper and Row publications, 1999.*
2. *Antoniou A., "Digital Filters – Analysis and Design", Tata Mc-Graw Hill, 1991.*
3. *Oppenheim and Schaffer, 'Discrete time Signal processing', PHI, 1999.*
4. *P.P. Vaidhyanathan, " Multirate systems and filter banks", PHI, 1993.*

EE672-DIGITALSIMULATIONOFPOWERELECTRONICSYSTEMS

Review of numerical methods. Application of numerical methods to solve transients in D.C.Switched R, L, R-L, R-C and R-L-C circuits. Extension to AC circuits.

Modeling of diode in simulation. Diode with R, R-L, R-C and R-L-C load with ac supply. Modelling of SCR, TRIAC, IGBT and Power Transistors in simulation. Application of numerical methods to R, L, C circuits with power electronic switches. Simulation of gate/base drive circuits, simulation of snubber circuits.

State space modeling and simulation of linear systems. Introduction to electrical machine modeling: induction, DC, and synchronous machines, simulation of basic electric drives, stability aspects.

Simulation of single phase and three phase uncontrolled and controlled (SCR) rectifiers, converters with self commutated devices- simulation of power factor correction schemes, Simulation of converter fed dc motor drives ,Simulation of thyristor choppers with voltage, current and load commutation schemes, Simulation of chopper fed dc motor.

Simulation of single and three phase inverters with thyristors and self-commutated devices, Space vector representation, pulse-width modulation methods for voltage control, waveform control. Simulation of inverter fed induction motor drives.

1. *Simulink Reference Manua , Math works, USA.*
2. *Robert Ericson, 'Fundamentals of Power Electronics', Chapman & Hall, 2001.*
3. *Issa Batarseh, 'Power Electronic Circuits', John Wiley, 2004.*
4. *Simulink Reference Manua , Math works, USA.*

EE674-PWMCONVERTERSANDAPPLICATIONS

AC/DC and DC/AC power conversion, overview of applications of voltage source converters, pulse modulation techniques for bridge converters.

Bus clamping PWM, space vector based PWM, advanced PWM techniques, practical devices in converter; calculation of switching and conduction losses.

Compensation for dead time and DC voltage regulation; dynamic model of a PWM converter, multilevel converters; constant V/F induction motor drives.

Estimation of current ripple and torque ripple in inverter fed drives; line – side converters with power factor compensation.

Active power filtering, reactive power compensation; harmonic current compensation.

1. *Mohan, Undeland and Robbins,' Power Electronics; Converters, Applications and Design',John Wiley and Sons,2nd edition , 1995.*
2. *Erickson R W,' Fundamentals of Power Electronics', Chapman and Hall, 2001.*
3. *Vithyathil J,'Power Electronics: Principles and Applications ', McGraw Hill, 1995.*