M.Tech. Programme

in

POWER ELECTRONICS

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 Electronics is 62.

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
	Total	18	0	3	18

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					
EE661	Advanced Power System Analysis	3	0	0	3
EE663	Analysis and Design of Artificial Neural Networks	3	0	0	3
EE665	Digital System Design	3	0	0	3
	Any One course from other department				
Group II elective subjects recommended for 2nd semester					
EE660	Flexible AC Transmission Systems	3	0	0	3
EE662	Computer Networking	3	0	0	3
EE664	Fuzzy Systems	3	0	0	3
EE666	Principles of VLSI Design	3	0	0	3

Or any one course from other departments.

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.

EE671	Modeling and Analysis of Electrical Machines	3	0	0	3
EE672	Renewable Power Generation Sources	3	0	0	3
EE673	Power System Operation and Control	3	0	0	3
EE674	Electrical Distribution Systems	3	0	0	3
EE675	Power System Planning and Reliability	3	0	0	3
EE676	Advanced Power System Protection	3	0	0	3
EE677	Digital Simulation of Power Electronic Systems	3	0	0	3
EE678	Stochastic Models and Applications	3	0	0	3
EE679	PWM Converters and Applications	3	0	0	3
EE680	Transient over voltages in power systems	3	0	0	3
EE681	High Voltage DC Transmission	3	0	0	3
EE682	Embedded System Design	3	0	0	3
EE683	Computer Relaying and wide area measurement systems	3	0	0	3
EE684	Architecture and programming for TMS320C6X DSK	3	0	0	3
EE685	Power System Restructuring	3	0	0	3

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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, 1978.*
2. *Taha,H.A., Operations Research –An Introduction, Prentice Hall of India.*
3. *Fox, R.L.,'Optimization methods for Engineering Design', Addition Welsey, 1971.*

EE651 – POWER CONVERTERS

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, 1995.*
2. *Rashid M.H., 'Power Electronics Circuits, Devices and Applications ', Prentice Hall India, New Delhi, 1995.*
3. *P.C Sen.,' Modern Power Electronics ', Wheeler publishing Co, First Edition, New Delhi, 1998.*

EE653 – 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 – Fibre 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.

4. James Mass, "Industrial Electronics", Prentice Hall, 1995.

EE655- 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

EE657 – POWER CONVERTERS LABORATORY

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

EE652 – SWITCHED MODE POWER CONVERSION

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 feedback 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.*

EE654 - 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 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.*

EE656 –MICROCONTROLLER 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.

ELECTIVES

EE661 – ADVANCED POWER SYSTEM ANALYSIS

Single phase and three phase modeling of Synchronous generators, transformers, transmission lines and shunt components – per unit representation - network modeling – Y_{bus} formulation & Conditioning – Z_{bus} formulation - DC system modeling

Load flow – Gauss Seidal method - Newton Raphson method - Decoupled & Fast decoupled methods - three-phase load flow.

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

Fault Studies -Analysis of symmetrical and unsymmetrical faults – open circuit faults.

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.

EE663–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-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'*

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, 1996.*

EE665 – DIGITAL SYSTEM DESIGN

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

Digital system design Hierarchy, 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. *Donald D.Givone, "Digital principles and design", Tata Mc-Graw Hill, 2003*

2. *Morris Mano, " Digital Design", 3rd Edition, Prentice Hall of India, 2001.*

3. *Samuel C.Lee, "Digital circuits and logic design", Prentice Hall of India, 1998.*

4. *N.N.Biswas, "Logic Design Theory", Prentice Hall of India, 1993.*

EE660 –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. 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*

EE662 – 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 :TCP congestion control, connection management-UDP-header format,RPC.

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. May

EE664 - 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,1966*
2. *Klir, G.J., and Folge., T., 'Fuzzy sets, uncertainty and information', PHI, New Delhi,1991.*
3. *EarlCox,,'The Fuzzy Systems Handbook', AP professional Cambridge,*

   MA 02139, 1994.

EE666 – PRINCIPLE OF VLSI DESIGN

MOS and Fabrication: VLSI technology- NMOS, CMOS and BICMOS circuit fabrication. Comparison of IC technologies. Operation characteristics, design equations, models and second order effects of MOS transistors, Fabrication of resistors and capacitors. Latch up, Driver circuits.

Hardware Description languages: VHDL- Modeling styles –Design of simple/ complex circuits using VHDL. Overview of Verilog HDL -Design of simple circuits using Verilog HDL.

CMOS Logic Circuits: Implementation of logic circuits using MOS and CMOS, Pass transistor and transmission gates – Implementation of combinational and sequential circuits – memory design.

Programmable Devices: Simple and Complex Programmable logic devices (SPLD and CPLDs) , Field Programmable Gate Arrays (FPGAs), Internal components of FPGA, Case study: A CPLD and a 10 million gates type of FPGA.

ASIC : Types of ASICs-Design flow-Programmable ASICs-Programmable ASIC logic cells and interconnect for Xilinx and Altera families.

1. *Neil Weste, David Harris, "CMOS VLSI Design: A Circuits and Systems Perspective", (4th Edition), Addison-Wesley, 2010*
2. *M. J. Smith, 'Application Specific Integrated Circuits', Addison Wesley, 1997.*
4. *Uyemura, 'Introduction to VLSI Circuits and Systems', Wiley, 2002.*
5. *J. Bhaskar, "Verilog HDL Primer", BPB publications, 2000.*

RESERVE ELECTIVES

EE671 - MODELING AND ANALYSIS OF ELECTRICAL MACHINES

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.*

EE672 - 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*

EE673 – 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.*
2. *Kirchmayer L.K., 'Economic Operation of Power System', John Wiley & Sons, 1953.*
3. *Kirchmayer L.K., 'Economic Control of Interconnected Systems', John Wiley & Sons, 1959.*

EE674- 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', Tata McGraw hill, 1981.*

2. *Tuvar Goner, 'Electrical Power Distribution System Engineering', McGraw hill, 1986.*

3. *Sterling, M.I.H., ''Power System Control', Peter Peergisus, 1978.*

EE675 – 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

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, 1977*

2. *Roy Billington, `Power System Reliability Evaluation', Gordan & Breach Scain Publishers, 1970.*

3. *Dhillan, B.S., 'Power System Reliability, Safety and Management', An Arbor Sam, 1981.*

EE676- 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.

Reacter 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.*

EE677- DIGITAL SIMULATION OF POWER ELECTRONIC SYSTEMS

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, 1997.*
3. *Issa Batarseh, 'Power Electronic Circuits', John Wiley, 2004Simulink Reference Manua , Math works, USA.*

EE678- 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,1981.*

EE679- PWM CONVERTERS AND APPLICATIONS

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, 1989.*
2. *Erickson R W,' Fundamentals of Power Electronics', Chapman and Hall, 1997.*
3. *Vithyathil J,'Power Electronics: Principles and Applications ', McGraw Hill, 1995*

EE680 - 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- 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, 1971.*
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, 1982.*

EE681– 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

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.1983.*
3. *Padiyar, K.R., 'HVDC transmission systems', Wiley Eastern Ltd., New Delhi, 1992*.

EE682 EMBEDDED SYSTEM DESIGN

Embedded System Architectures – ARM processor and SHARC processor - architectural design - memory organization - data operation - bus configurations. System on-chip, scalable bus architectures, Design example: Alarm clock, hybrid architectures.

Sensor and Actuator I/O – ADC, DAC, timers, Servos, Relays, stepper motors, H-Bridge, CODECs, FPGA, ASIC, diagnostic port.

Real time operating systems (RTOS) – real time kernel – OS tasks – task states – task scheduling – interrupt processing – clocking communication and synchronization – control blocks – memory requirements and control – kernel services.

Embedded Networks - Distributed Embedded Architecture – Hardware and Software Architectures, Networks for embedded systems– I2C, CAN Bus, Ethernet, Internet, Network–Based design– Communication Analysis, system performance Analysis, Hardware platform design, Allocation and scheduling, Design Example: Elevator Controller.

System Design – Specification, Requirements and Architectural design of PBX systems, Set-top box, Ink-jet printer, Laser printer, Personal digital Assistants.

1. *Wayne Wolf, "Computers as Components: Principles of Embedded Computing System Design", Morgan Kaufman Publishers, 2008.*
2. *C.M. Krishna, Kang G. Shin, "Real time systems", Mc-Graw Hill, 2010.*
3. *Gajski D. D., Vahid F., Narayan S., "Specification and Design of Embedded Systems", Prentice Hall, 1994.*
4. *Herma K., "Real Time Systems: Design for Distributed Embedded Applications", Kluwer Academic, 1997.*
5. *William Hohl, "ARM Assembly Language, Fundamentals and Techniques", CRC Press, 2009.*

EE683 -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*
2. *A.G. Phadke , J.S. Thorp, 'Synchronized Phasor Measurements and Their Applications', Springer Publications, 2008*

EE684- 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.*
2. *Real-Time digital signal processing based on the TMS320C6000 by Nasser Kehtarnavaz, ELSEVIER publication*
3. *DSP applications using C and the TMS320c6x DSK by Rulph Chassaing, Wiely publication.*

EE685 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.*