Biju Patnaik University of Technology, Orissa

M.Tech. Syllabus

in

Power Electronics & Drives

From
2009 -2010 Academic Session

M.Tech (Power Electronics & Drives)

Sem – I

Professional Core	:	PEPC101	Power Converter - I
		PEPC102	Power Apparatus and Systems
		PEPC103	Electric Drives - I
Electives –I (any one):		PEPE101	Advanced Microprocessor & Micro Controller
			OR
		PEPE102	Soft Computing.
Electives –II (any one):		PEPE103	Optimization Techniques
			OR
		PEPE104	Power System Transient.
Sessional	:	PEPR101	Modelling & Simulations
Seminar	:	PEPT101	Pre Thesis Work related Seminar

Sem – II

Professional Core	:	PEPC201	Power Converter II.
		PEPC202	Electric Drives II
Electives	:	EL- 3 (Any One of the following)	
		EEPE201	HVDC & FACTS
		EEPE205	Advanced Digital Signal Processing.
		CSPE210	Embedded System
		EL- 4 (Any One of the following)	
		EEPE204	Advanced Control Systems.
		EEPC202	Power System Dynamics
		PEPE201	System Identification & Adaptive Control
		EL- 5 (Any One of the following)	
		PEPE202	Power Quality
		PEPE203	Instrumentation & Sensors
		PEPE204	Electrical Energy System
Sessional	:	PEPR201	Power Electronics Lab
Seminar	:	PEPT201	Pre Thesis Work related Seminar.
Comp. Viva Voce	:	PECV201	Viva Voce - 1

Sem – III

Open Electives	:	PEOE301	a) Project Management
			OR
		PEOE302	b) Energy Management
			OR
		PEOE303	c) Industrial Management.
Thesis-Part-I	:	PEPT301	TH – I

Sem- IV

Thesis-Part-II	:	PEPT401	TH – II
Seminar	:	PECV401	Seminar-3
Comp. Viva Voce	:	PECV402	Viva Voce- 2

PEPC101 **POWER CONVERTER-I**

Module-I (12 hours)

Phase controlled rectifiers– Single phase half wave controlled rectifier with R, R-L, R-L with freewheeling diodes.Full wave controlled rectifier with various kind of loads. Half controlled and full controlled bridges with passive and active loads-Input line current harmonics and power factor-Inverter mode of operation.Three phase half wave controlled rectifier with R,R-L an R-L-E loads.Thre phase semi and full converters with RL and RLE loads.Input side current harmonics and power factor. Dual converters-Circulating current mode and Non circulating current mode.

Module-II (12 hours)

AC voltage regulators and DC Choppers-Types of ac voltage regulators-single phase full wave ac voltage controllers-single phase transformer tap changers-Multistep transformer tap changer. Three phase ac voltage regulators. Output performance analysis of type A chopper, four quadrant chopper operation.

Module-III (14 hours)

Switch-mode dc-ac inverters. Basic concepts, single phase inverters,push pull, half bridge and full bridge square wave inverters, Blanking time, Single pulse modulation of single phase square wave inverters,Multi pulse modulation-PWM principle, Sinusoidal PWM in single phase inverters,Choice of carrier frequency in SPWM,Spectral content in the output,Unipolar and Bipolar switching in SPWM-Maximum attainable dc voltage,Switch utilization, Reverse recovery problem and Carrier frequency selection,Output side filter requirements and filter design-Ripple in the inverter output-DC side current,Three phase inverters-Three phase square wave/stepped wave inverters.Three phase SPWM inverters,Output filters,DC side current, Effect of blanking time on inverter output voltage.

Text/References:

1. Ned Mohan et. al : Power Electronics ,John Wiley and Sons
2. P C Sen : Power Electronics , TMH
3. G K Dubey et. al : Thyristorised Power Controllers , Wiley Eastern Ltd.
4. B K Bose : Modern Power Electronics and AC Drives, Pearson Edn (Asia)

PEPC102 **POWER APPARATUS AND SYSTEMS**

Module-I **(12 Hrs)**

Synchronous Machines: The basis of General Theory and Generalized Equation of A.C machines, Equation in terms of phase variable Park's transformation, Various reference frames, Derivation of two-axis equation, Torque equation, Field and damper windings, Equivalent circuits, Operational impedances and frequency response loci, Modified equation with more accurate coupling between field and damper windings.

Selected topics on prime mover and energy supply systems: Governors for hydraulic and steam turbines, Transient droop, speed governing system.

Module-II **(12 Hrs)**

Synchronous Generator short circuit and system faults: Symmetrical short circuit of unloaded generator, Analysis of short circuit oscillograms, short circuit of loaded synchronous generator, Unsymmetrical short of synchronous generator, system fault calculation, Sudden load changes, Equivalent circuit under transient condition, Constant flux linkage theorem, Simplified phasor diagram for transient changes.

Selected topics on excitation systems: Modeling of excitation system components, exciter (D.C and A.C), Amplifier, Stabilizing circuit

Module-III **(12 Hrs)**

Induction machines: Generator equation of the induction motor (equation), Application of equation in primary and secondary reference frames and complex form of equation, Short circuit and fault current due to the induction motor, fault calculation.

Transformers: Transient phenomena in transformer and transformer protection: General characteristics of over voltage and current inrush, Transient over voltage characteristics, Ferro resonant over voltages, protection against surges and insulation co-ordination.

BOOKS RECOMMENDED :

1. *The Generalized theory of electrical machines (Chapters: 1,2,34,5,8 and 11 by B.Adkins and R.H. Hiiley.*
2. *Principle, Operation and Design of power Transformer By S.B Vasciitnsky.*
3. *The J & P transformer Book (Chapter: 22&23) By S. Austen Stigant and A.C Franklin.*
4. *Power System Stability & Control (Chapters: 8&9) By P.Kundur, McGraw Hill-1994.*

PEPC103 **ELECTRIC DRIVES- I**

Module-I **12hrs**

Introduction to motor drives: Components of power electronic Drives- Criteria for selection of Drive components-match between the motor and the load- Thermal consideration- match between the motor and the power electronics converter- characteristics of mechanical systems- stability criteria.

DC Motor Drives: System model, motor rating, motor-mechanism dynamics-Drive transfer function.

Module- II **14hrs**

Phase controlled D C Motor Drives- Steady state analysis of the 3-phase converter controlled DC motors Drive , Steady state solution including Harmonics, Discontinuous current conduction, Transfer functions of the sub systems, two quadrant dc motor drive with field weakening. Four quadrant dc motor drive.

Chopper- Controlled DC motor drive:
Four quadrant chopper circuit, chopper for inversion. Model of the chopper, steady state analysis of chopper- controlled dc motor drive – continuous and discontinuous conduction operation, closed-loop operation.

Module-III **12hrs**

Induction motor drives: Torque speed characteristics of 3-phase induction motor drive, speed control of 3-phase induction motor by varying stator frequency and voltage – impact of non sinusoidal excitation on induction motors- variable frequency converter classifications – variable frequency PWM-VSI drives- variable frequency square wave VSI drives- variable frequency CSI drives-comparison of variable frequency drives- Line frequency variable voltage drives- soft start of induction motors – speed control by static slip power recovery, static Cramer and Scherbius drives.

Text / Reference

1. Ned Mohan etial : Power Electronics , John wiley and sous

2. R.Krishnan :Electric Motor Drives – PHI publication

3. B K Bose :Modern Power Electronics and AC drives, Pearson Education (Asia)

4. P C Sen : Power Electronics TMH Publication

5. Dubey : Power Electronics Drives- Wiley Eastern

PEPE101 **ADVANCED MICROPROCESSOR AND MICROCONTROLLER**

Module I **(10 Hours)**

(Prerequisite: A basic course on 8 bit ups such as 8085)

16-bit microprocessor(one well known processor, say 8086 to 68000 to be taken as case study)-quick overview of the instruction set, Assembly language programming. Interrupt structure, Interfacing memory and I\O devices. Memory organizations.

Standard peripherals and their interfacing-(s\w and h\w aspects) color graphic terminals and ASCII keyboards, mouse, floppy and hard disc drive, other storage media (optical disks, Digital Audio Tapes etc.)

Module II **(10 Hours)**

Data transfer techniques-Asynchronous and synchronous. Serial and parallel interface standards. Communication media and adapters. Modems and their interfacing.

Bus structures and standards-basic concepts. Example of a bus standard (PC\-VME bus).

Salient features of other processors (80286\386\486 or 68020\68030\68040). Microcontrollers and digital signal processors. I\O processors and arithmetic coprocessors.

Logic design for microprocessor-based systems-design of state.

Module III **(10 Hours)**

Introduction to Microcontrollers - Motorola 68HC11 - Intel 8051 - Intel 8096 - Registers - Memories - I/O Ports - Serial Communications - Timers - Interrupts.

Text/References

1. John.F.Wakerly: Microcomputer Architecture and Programming, John Wiley and Sons.
2. Ramesh S.Gaonker: Microprocessor Architecture, Programming and Applications with the 8085, Penram International Publishing (India).
3. Yu-Cheng Liu and Glenn A.Gibson: Microcomputer systems: The 8086/8088 Family Architecture, Programming and Design, Prentice Hall of India.
4. Raj Kamal: The Concepts and Features of Microcontrollers, Wheeler Publishing.

PEPE102 **SOFT COMPUTING**

Module-I **12hrs**

Basic tools of soft computing – Fuzzy logic, neural network , evolutionary computing.

Fuzzy Logic System:Basic of fuzzy logic theory , crisp and fuzzy sets, Basic set operation like union , interaction , complement , T-norm , T-conorm , composition of fuzzy relations, fuzzy if-then rules , fuzzy reasoning.

Fuzzy inference System:

Zadeh's compositional rule of inference, defuzzification , Mamdani Fuzzy Model, Sugeno Fuzzy Model,
Introduction to type –II Fuzzy System.

Module-II **20hrs**

Neural Network:

Supervised NN:Single layer network, Perception , Activation function, Adaline , Gradient descent method, least square training algorithm, Multilayer perceptron , error back propagation, generalized delta rule, Radial Basis Function Network, interpolation and approximation RBFNS, comparison between RBFN and MLP, Support Vector Machines : Optimal hypeplane for linearly separable patterns, optimal hyperplane for non-linearly separable patterns. Inverse Modeling.

Unsupervised NN and other NN:Competitive learning networks, kohonen self organizing networks, learning vector quantization, Hebbian Learning Hopfield Network: Content addressable nature, binary and continuous valued Hopfield network , simulated annealing NN. Recurrent Neural Network: NARX Model , Simple Neural Network , State – Space Model , Back Propagation Through Time (BPTT) Algorithm , Real-time Recurrent Learning (RTRL) Algorithm.

Neuro-Fuzzy Modeling: Adaptive Neuro-Fuzzy Inference System (ANFIS) , ANFIS architecture , Hybrid Learning Algorithm , modeling of a three input nonlinear function , simulation of on-line identification in control system.

Data Clustering Algorithms-k-means clustering, fuzzy c-means clustering , subtractive clustering.

Module –III **8hrs**

EVOLUTIONARY AND BIO INSPIRED COMPUTING

Evolutionary computing: Genetic algorithm: Basic concept , encoding , fitness function , Reproduction , Basic genetic programming concepts , differences between GA and Traditional optimization methods , Applications, Variants of GA.

Bio Inspired optimization Techniques: Particle Swarm optimization , Ant colony optimization, Bacteria foraging method , Applications.

Text Book

1. *Neuro-Fuzzy and soft computing by J S R Jang, CT Sun and E.Mizutani , PHI PVT LTD.*
2. *Principles of soft computing –by sivandudam and Deepa publisher –John mikey India.*

Reference Book

S.haykins- Neural Networks: A comprehensive foundation.

PEPE103 **Optimization Techniques**

Module-I **12hrs**

Optimization Fundamentals:
Definition , classification of optimization problems, Unconstrained and constrained optimization, optimality conditions.
Linear Programming:
Simplex Method, Duality, Sensitivity methods.

Module-II **14hrs**

Nonlinear Programming:
Powel's method, steepest descent method, conjugate gradient method, Newton's Method GRG method, Sequential quadratic programming, Penalty function method, Augmented Lagrange multiplier method.

Dynamic Programming and Integer Programming
Interior point methods
Karmakar's algorithm , Dual affine, Primal affine , Barrie algorithm.

Module-III **10 hrs**

Simulated annealing , Evolutionary Programming , Genetic algorithm and Genetic Engineering.
Finite Element Based Optimization.

Reference Books

1. Ashok D.belegundu and Chrandrapatla T. R " Optimization Concept and Application in Engineering " Prentice Hall, 1999.
2. Rao S.S " Engineering Optimization"
3. Gill , Murray and Wright ," Practical Optimization"
4. James A. Memoh." Electic Power System Application of optimization."
5. song Y. , "Modern Optimization Techniques in power System"

PEPE104 **POWER SYSTEMS TRANSIENTS**

Module-I **(12 Hours)**

INTRODUCTION TO FAST TRANSIENTS:

Origin and nature of power system Transients, traveling waves on transmission system, the line equation, the shape attenuation and distortion of waves, reflection of traveling waves , successive reflections, traveling waves on multi conductor systems, transition points on multi conductor circuits.

LIGHTNING :

Charge formation , mechanism of lightning stroke. Mathematical model of lightning stroke.

Module-II **(12 Hours)**

THEORY OF GROUNDS WIRES :

Direct stoke to a tower, effect of reflection up and down the tower , the counterpoise.

SWITCHING SURGES :

Normal frequency effects, high charging currents, cancellation waves, recovery voltage, restricting phenomena. Protection of transmission systems against surge.

HIGH FREQUENCY OSCILLATIONS AND TERMINAL TRANSIENTS OF TRANSFORMER

Module-III **(12 Hours)**

INSULATION COORDINATION:

Insulation coordination procedures (IEC) for high voltage systems: Design criteria, classification of overvoltages, insulation design for switching, lightning and temporary overvoltages, pollution, application of arresters for protection of lines and stations, statistical methods of insulation coordination, risk of failure, test prescriptions. Insulation coordination procedures (IEC) for low voltage systems: representative overvoltages, selection of clearance and creepage distances, macro and micro environments, testing techniques, transient (switching and lightning) voltage surge suppression in industrial and commercial electrical installations, protection of electronic devices.

REFERENCES

1.Allan Greenwood , Electrical Transients in power Systems , Wiley Iterscience, 1991
2.Lou Van Der Sluis, Transients in power Systems , John Wiley & Sons Ltd, 2001
3.R Rudenterg, Transient Performance of Electric power systems, Phenomenon in Lumped Networks, MGH, 1950
4.R Rudenterg, Electric Stroke waves in power systems, Harvard University press, Cambridge, Massachusetts, 1968
5.Transmission Line Reference Book, EPRI, USA, 1982

2nd Semester

Power Converter-II

Module . 1(15 hours)
Switched Mode Rectifier - Operation of Single/Three Phase Bridges in Rectifier Mode . Control Principles . Control of the DC Side Voltage.Voltage Control Loop. The inner Current Control Loop. Special Inverter Topologies - Current Source Inverter . Ideal Single Phase CSI operation, analysis and waveforms - Analysis of Single Phase Capacitor Commutated CSI. Series Inverters . Analysis of Series Inverters . Modified Series Inverter . Three Phase Series Inverter.

Module . 2 (15 Hours)
Multi-Level Inverters of Diode Clamped Type, Flying Capacitor Type and Cascaded type; Basic Topology and Waveforms, Improvement in harmonics, High Voltage Applications: load compensation, series compensation, suitable modulation strategies - Space Vector Modulation - Minimum ripple current PWM method. Current Regulated Inverte*r* -Current Regulated PWM Voltage Source Inverters . Methods of Current Control . Hysteresis Control . Variable Band Hysteresis Control . Fixed Switching Frequency Current Control Methods . Switching Frequency Vs accuracy of Current Regulation . Areas of application of Current Regulated VSI .

Module . 3(15 hours)
Buck, Boost, Buck-Boost SMPS Topologies . Basic Operation- Waveforms - modes of operation – Output voltage ripple Push-Pull and Forward Converter Topologies - Basic Operation . Waveforms - Voltage Mode Control.
Half and Full Bridge Converters . Basic Operation and Waveforms- Flyback Converter . discontinuous mode operation . waveforms . Control - Continuous Mode Operation . Waveforms
Introduction to Resonant Converters . Classification of Resonant Converters . Basic Resonant Circuit Concepts . Load Resonant Converter . Resonant Switch Converter . Zero Voltage Switching Clamped Voltage Topologies . Resonant DC Link Inverters with Zero Voltage Switching . High Frequency Link Integral Half Cycle Converter. Introduction to active power factor control.

Texts/References:

1. Ned Mohan et.al : Power Electronics,John Wiley and Sons
2. Rashid :Power Electronics, Prentice Hall India
3. G.K.Dubey et.al :Thyristorised Power Controllers, Wiley Eastern Ltd.

ELECTRIC DRIVES-II

Module I(15 Hours)

Principles for vector and field-oriented control-Complex-valued *dq*-model of induction machines. Turns ratio and modified *dq*-models. Principles for field-oriented vector control of ac machines. Current controllers in stationary and synchronous coordinates. Rotor-flux oriented control of current-regulated induction machine - Dynamic model of IM in rotor-flux coordinates. Indirect rotor-flux oriented control of IM - Direct rotor-flux oriented control of IM.- Methods to estimation of rotor-flux

Generalized flux-vector control using current- and voltage decoupling networks- Generalized flux-vector oriented control. Current and voltage decoupling networks. Airgap-oriented control. Voltage-fed vector control. Stator-flux oriented vector control.

Module II(15 Hours)

Parameter sensitivity, selection of flux level, and field weakening - Parameter detuning in steady-state operation. Parameter detuning during dynamics. Selection of flux level. Control strategies for used in the over-speed region .

Module III(15 Hours)

Principles for speed sensor-less control - Principles for speed sensor-less control. Sensor-less methods for scalar control. Sensor-less methods for vector control .Introduction to observer-based techniques . Direct torque control Induction Motor Drives. Self control synchronous motor drives. Introduction to speed control of switched reluctance machine. Control of Permanent magnet synchronous machine, Brushless dc Machine, Surface Permanent Magnet Machine and interior.

Essential Reading:

1. B. K. Bose, *Modern Power Electronics and A.C. Drives*, PHI, 2002.
2. G. K. Dubey, *Power Semiconductor Controlled Drives*, Prentice-Hall International, 1989.

Supplementary Reading:

1. G. K. Dubey, *Fundamentals of Electrical Drives*, Narosa Publishing House, 2002.
2. W. Leonhard, *Control of Electrical drives*, Springer-Verlag, 1985.
3. P.C. Sen,*Thyristor DC Drives*,Wiley-Interscience Pub., Digitized on Dec, 2006.

HVDC & FACTS (3:1:0)

Module-I(15 hours)

Introduction: Comparison of AC-DC Transmission, Description and application of HVDC transmission, DC System components and their functions

Analysis of HVDC Converters: Pulse number, Converter configuration, Analysis of Graetz circuit, Bridge characteristics, 12 pulse converter

HVDC Control: Principles of DC Link control-Converter control characteristics- System control, Firing angle control- Current and extinction angle control, DC link power control, Reactive power control and VAR sources, MTDC system- types- control and protection- DC circuit breakers

Module-II(15 hours)

FACTS Concept and General System:

Transmission interconnections, Flow of power in AC system, Power flow and dynamic stability considerations of a transmission interconnection, Relative importance of controllable parameters, Basic types of FACTS controllers, Benefits from FACTS Technology, In-perspective: HVDC or FACTS

Module-III (15hours)

Compensators: Objective of series and shunt compensation, SVC and STATCOM, GCSC, TSSC, TCSC, and SSSC, UPFC, IPFC, Generalized and Multifunctional FACTS Controllers

Books Recommended

1.Padiyar K.R., “HVDC Power Transmission System”, Wiely Eastern PVT Limited
2.Kimbark, “Direct Current transmission”, Vol.1, John Wielly, New York, 1971
3.Understanding FACTS: Cocepts and Technology of Flexible AC Transmission Systems. By N. G. Hingorani & L. Gyugi, Standard Publisher Distributors,IEEE Press, Delhi
4.Flexible AC Transmission Systems. By J. Arillage

ADVANCED DIGITAL SIGNAL PROCESSING

Module-I: (15 hours)
Discrete time signals, systems and their representations:
Discrete time signals- Linear shift invariant systems- Stability and causality- Sampling of continuous time signals- Discrete time Fourier transform- Discrete Fourier series- Discrete Fourier transform- Z- transform- Properties of different transforms- Linear convolution using DFT- Computation of DFT

Module II: (15 hours)
Digital filter design and realization structures

Design of IIR digital filters from analog filters- Impulse invariance method and Bilinear transformation method- FIR filter design using window functions- Comparison of IIR and FIR digital filters- Basic IIR and FIR filter realization structures- Signal flow graph representations

Module III (15 hours)
Analysis of finite word-length effects
Quantization process and errors- Coefficient quantisation effects in IIR and FIR filters- A/D conversion noise- Arithmetic round-off errors- Dynamic range scaling- Overflow oscillations and zero input limit cycles in IIR filters

Statistical signal processing

Linear Signal Models . All pole, All zero and Pole-zero models .Power spectrum estimation- Spectral analysis of deterministic signals . Estimation of power spectrum of stationary random signals-Optimum linear filters-Optimum signal estimation-Mean square error estimation-Optimum FIR and IIR filters.

Texts/ References

1. Sanjit K Mitra, Digital Signal Processing: A computer-based approach ,Tata Mc Grow-Hill edition .1998
2. Dimitris G .Manolakis, Vinay K. Ingle and Stephen M. Kogon, Statistical and Adaptive Signal Processing, Mc Grow Hill international editions .-2000
3. Alan V . Oppenheim, Ronald W. Schafer, Discrete-Time Signal Processing, Prentice-Hall of India Pvt. Ltd., New Delhi, 1997
4. John G. Proakis, and Dimitris G. Manolakis, Digital Signal Processing(third edition), Prentice-Hall of India Pvt. Ltd, New Delhi, 1997
5. Emmanuel C. Ifeachor, Barrie W. Jervis , Digital Signal Processing-A practical Approach, Addison . Wesley,1993
6. Abraham Peled & Bede Liu, Digital Signal Processing,John Wiley & Sons, 1976

EMBEDED SYSTEM

Module-I (15 Hours)

Introduction: An embedded system, Processor in the system, Other hardware units, Software embedded into a systems, exemplary system-in-chip

Devices and Device Drivers : I/O devices, Timer and counting devices, serial communication using the IC, CAN and advance I/O buses between the networked multiple devices. Host system or computer parallel communication between the networked I/O multiple devices using the ISA, PCI, PCI-X and advance buses. Device drivers, Parallel port devices drivers in a system, Serial port device drives in a system, Interrupt servicing (Handling) mechanism.

Module-II (15 Hours)

Software and Programming Concept : Processor selection for an embedded system, memory selection for an embedded system, Embedded programming in C++, Embedded programming in JAVA, Unified modeling language (UML), Multiple processes and application, problem of sharing data by multiple tasks and routines, Inter process communication.

Real time Operating System: Operating system services, I/O subsystem, Network operating system, Real Time and embedded system, Need of well tested and debugged Real Time operating system (RTOS), Introduction to C/OS-II.

Case studies of programming with RTOS : Case study of an embedded system for a smart card

Module-III (15 Hours)

Hardware and Software Co-design : Embedded system project management, Embedded system design and co-design issues in system development process, design cycle in the development phase for an embedded system, Use of software tools for development of an embedded system, Issues in embedded system design.

References:

1...Embedded System Architecture, Programming and Design, Raj Kamal, TMH
2.Hardware Software Codesign of Embedded System, Ralf Niemann, Kulwer Academic
3.Embedded Real time system Programming, Sriram V. Iyer and Pankaj Gupat, TMH

ADVANCED CONTROL SYSTEMS

Module-I : ***(15 Hours)***

Digital Control **:** State Space Representations of Discrete Time Systems, Solution of Discrete Time State Equations, Discretization of Continuous Time State Equations. Controllability and observability of Linear Time Invariant Discrete Data Systems, Pole Placement, Deadbeat response, Digital Simulation.

Module -II : ***(15 Hours)***

Optimal Control : Performance Indices, Quadratic Optimal Regulator / Control Problems, Formulation of Algebraic Riccati Equation (ARE) for continuous and discret time systems. Solution of Quadratic Optimal Control Problem using Logrange Multiplies for continuous and discrete-time systems. Evaluation of the minimum performance Index, Optimal Observer, The Linear Quadratic Gaussia (LQG) Problem, Introduction to H_∞ Control.

Module - III : ***(15 Hours)***

Non linear Systems **:** The Aizerman and Kalman Conjectures : Popov's stability criterion, the generalized circle criteria, simplified circle criteria. Simple variable structure systems, sliding mode control, feedback linearization, Model reference adaptive control, (MRAC), Self Tuning Regulator (STR).

Fuzzy Logic Control **:** Fuzzy sets and crispsets, Fuzzy Relations and composition of Fuzzy Relations, Introduction to Fuzzy Logic Controllers.

Books :

1. Discrete Time Control Systems, by K.Ogata, 2nd edition (2001), Pearson Education publication.
2. Digital Control Systems, by B.C. Kuo, 2nd edition (1992), Oxford University Press.
3. Digital Control and State Variable Methods, by M.Gopal, 3rd edition (2009), Tata Mc. Graw Hill Education Pvt. Ltd.
4. Systems and Control by Stanislaw H.Zak, Oxford University Press (2003).
5. Design of Feedback Control Systems by Raymond T. Stefani, B.Shalia, Clement J. Savant, Jr. Gen H. Hostetter, 4th edition (2002), Oxford University Press.
6. Introduction to Control Engineering (Modeling, Analysis and Design) by Ajit K. Mandal, New Age International (P), Ltd., Publishers (2006).
7. Non Linear Systems, by Hassan K. Khallil, 3rd edition (2002), Prentice Hall, Inc. (Pearson Education), Publications.
8. Control Theory (Multivariable and non linear Methods) by Torkel Glad & Lennart Ljung, Taylor & Francis (2009).

POWER SYSTEM DYNAMICS

Module-I (15 Hours)

Power System Stability Problems: Basic concepts and definitions, Rotor angle stability, Synchronous machine characteristics, Power versus angle relationship, Stability phenomena, Voltage stability and voltage collapse, Mid-term and long-term stability, Classification of stability.

Small Signal Stability: State space concepts, Basic linearization technique, Participation factors, Eigen properties of state matrix, small signal stability of a single machine infinite bus system,

Module-II (15 Hours)

Studies of parametric effect: effect of loading, effect of K_A, effect of type of load, Hopf bifurcation, Electromechanical oscillating modes, Stability improvement by power system stabilizers. Design of power system stabilizers.

Large Perturbation Stability: Transient stability: Time domain simulations and direct stability analysis techniques (extended equal area criterion)

Energy function methods: Physical and mathematical aspects of the problem, Lyapunov's method, Modeling issues, Energy function formulation, Potential Energy Boundary Surface (PEBS): Energy function of a single machine infinite bus system, equal area criterion and the energy function, Multimachine PEBS.

Module-III (15 Hours)

Sub Synchronous Oscillations: Turbine generator torsional characteristics, Shaft system model, Torsional natural frequencies and mode shapes, Torsional interaction with power system controls: interaction with generator excitation controls, interaction with speed governors, interaction with nearby DC converters, Sub Synchronous Resonance (SSR): characteristics of series capacitor – compensated transmission systems, self – excitation due to induction generator effect, torsional interaction resulting in SSR, Analytical methods, Counter measures to SSR problems.

Voltage stability, System oscillations

References:

1.Prabha. Kundur, *Power system stability and control*, Tata McGraw-Hill, 1994

2.P. Sauer and M. Pai, *Power system dynamics and stability*, Prentice Hall, 1998.

SYSTEM IDENTIFICATION AND ADAPTIVE CONTROL

Module-I (15 Hours)
Introduction and overview of Systems Identification, Adaptive Control and applications. Parameter Estimation: Least Square, Generalized and Recursive Least Square, Estimator properties including error bounds and convergence, MES, ML and MAP estimators, Nonlinear Least Squares. Model Structures and Predictors.

Module-II (15 Hours)
Recursive Identification of Linear dynamic systems: RLS, ELS, IV, RML, Stochastic Approximation, Extended Kalman Filter, generalized prediction error framework and its application to ARMA and state models, convergence analysis, Time varying parameters. Nonlinear System Identification. ; Adaptive schemes. Adaptive control theory. Applications. Situations when constant Gain feedback is insufficient. ; Robust control. ; The adaptive control problem. ; The model following problem. MRAS based on stability theory. Model following when the full state is measurable.

Module-III (15 Hours)
Direct MRAS for general linear systems. Prior knowledge in MRAS. MRAS for partially known systems. Use of robust estimation methods in MRAS. ; The basic idea. Indirect self-tuning regulators. Direct Self-tuning regulators. Linear Quadratic STR. Adaptive Predictive control. Prior knowledge in STR.; Linear-in-the-parameters model. Least squares estimation. Experimental conditions. Recursive estimators. Extended least squares. Robust estimation methods (dead zone, projection).Implementation issues. ; Nonlinear System Identification Techniques

Essential Readings:

1. K.J. Astrom and B. Wittenmark, *Adaptive Control*, Addison, Pearson 2006.
2. L. Ljung, *System Identification Theory for the user*, Prentice-Hall, 2007.

Supplementary Reading:

1. K.S. Narendra and A.M. Annaswamy, *Stable Adaptive Systems*, Prentice-Hall, 1989.
2. Landau and Zito, *Digital Control Systems: Design, Identification and Implementation*, Springer, 2006

EEPE104 **POWER QUALITY**

Module-I

Introduction: power quality (PQ) problem, Voltage sag, Swell , Surges, Harmonic, over voltages, spikes, Voltage fluctuations, Transients, interruption overview of power quality phenomenon , Remedies to improve power quality, power quality monitoring.

Interruptions: Definition, Difference between failure, outage, causes and origin of interruptions, limits for the interruption frequency, limits for the interruption duration , costs of interruption, overview of Reliability , evaluation to power quality, comparison of observations and reliability evaluation.

Module-II

Voltage Sag: Characterization of voltage sag , definition, causes of voltage sag , voltage sag magnitude , monitoring, theoretical calculation of voltage sag magnitude , voltage sag calculation in non-radial systems, meshed systems, voltage sag duration.

PQ considerations in Industrial Power Systems: voltage sag effects, equipment behavior of power electronic loads, induction motors , synchronous motors, computers, consumer electronics, adjustable speed AC drives and its operation. Mitigation of AC drives, Adjustable speed DC drive and its operation, mitigation methods of DC drives.

Module-III

Mitigation of Interruptions and Voltage Sags: Overview of mitigation methods- form fault to trip, reducing the number of faults, reducing the fault clearing time changing the power system, installing mitigation equipment, improving equipment immunity, different events and mitigation methods . System equipment interface- voltage source converter , series voltage controller , shunt controller , combined shunt and series controller.

Power Quality and EMC Standards: Introduction to standardization, IEC Electromagnetic compatibility standards, European voltage characteristics standards , PQ surveys.

Reference Book:

1. “ Understanding Power Quality Problems” by Math H J Bollen, IEEE Press.
2. Electrical power quality –R C Dugan, M.F,M Granghar, H.W.Beaty-TMH.

INSTRUMENTATION & SENSORS

Module-I(15 Hours)

Measurement error and uncertainty. Accuracy, confidence limits, confidence level. Measuring methods. Characteristics of measuring instruments. Voltage and current measurement. Frequency measurement.

Module-II (15 Hours)

Signals and noise. Signal conditioning: instrumentation amplifiers, sample and hold circuits, filters, current to voltage conversion analog multiplexers, isolation amplifiers. A/D and/a conversion: parallel, successive approximation and dual slope A/D converters.

Module-III (15 Hours)

Data acquisition systems. Virtual instrumentation. Sensors and transducers: temperature, geometric displacement, force, torque, vibration. Microprocessor and PC based Instrumentation system Design. Introduction to computer control of processes.

Text Book:

1. D.V. Murty, *Transducers and Instrumentation*, PHI, 2008.
2. C. S. Rangan, G. R. Sarma, V. S. V. Mani, *Instrumentation: Devices and Systems*, TMH, 2008.

References:

1. A.S. Morris, *Principles of Measurement and Instrumentation*, Prentice Hall, 2007.
2. J. Bouwens, *Digital Instrumentation*, TMH, 2002.

ELECTRICAL ENERGY SYSTEM

Module-I (15 Hours)

Non-renewable reserves and resources; renewable resources, Transformation of Energy. Solar Power: Solar processes and spectral composition of solar radiation; Radiation flux at the Earth's surface. Solar collectors. Types and performance characteristics. Applications.

Module-I (20 Hours)

Wind Energy: Wind energy conversion; efficiency limit for wind energy conversion, types of converters, aerodynamics of wind rotors, power ~ speed and torque ~ speed characteristics of wind turbines, wind turbine control systems; conversion to electrical power: induction and synchronous generators, grid connected and self excited induction generator operation, constant voltage and constant frequency generation with power electronic control, single and double output systems, reactive power compensation;

Module-I (10 Hours)

Characteristics of wind power plant. Applications. ; Tidal Energy: Wave characteristics. Conversion systems and their performance features. Application, Geothermal energy: Biological conversion of Energy.

Text Book

1. S. N. Bhadra, D. Kastha, S. Banerjee, *Wind Electrical Systems*: Oxford Univ. Press, 2005.

Reference:

1. S.A. Abbasi, N. Abbasi, *Renewable Energy Sources and Their Environmental Impact:* Prentice Hall of India, 2004.

Power Electronics and Drives Laboratory-I

1. 1-Ph Full wave controlled Converter
2. 3-Ph Full wave controlled converter
3. V/f control of Induction Motor
4 Resonant DC-DC Converter
5. Resonant DC-AC Converter
6. PWM Converter

Power Electronics and Drives Laboratory-II

1. Closed loop Control of DC Motor Drive
2. Four Quadrant Operation
3. Switch Mode Rectifier
4 Field Oriented Control of Induction Motor drive
5. Switched Reluctance Motor Drive

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