AFFILIATED INSTITUTIONS

ANNA UNIVERSITY, CHENNAI

REGULATIONS - 2009

M.E. HIGH VOLTAGE ENGINEERING

II TO IV SEMESTERS (FULL TIME) CURRICULUM AND SYLLABUS

SEMESTER II

SL. No.	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1.	HV9321	High Voltage Testing Techniques	3	0	0	3
2.	HV9322	Insulation Design of High Voltage Power Apparatus	3	0	0	3
3.	HV9323	High Voltage Switchgear	3	0	0	3
4.	HV9324	EHV Power Transmission	3	0	0	3
5.		Elective II	3	0	0	3
6.		Elective III	3	0	0	3
PRACTICAL						
7.	HV9325	High Voltage Laboratory	0	0	3	2
		TOTAL	**18**	**0**	**3**	**20**

SEMESTER III

SL. No.	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1.		Elective IV	3	0	0	3
2.		Elective V	3	0	0	3
3.		Elective VI	3	0	0	3
PRACTICAL						
4.	HV9331	Project Work (Phase-I)	0	0	12	6
		TOTAL	**9**	**0**	**12**	**15**

SEMESTER IV

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
PRACTICAL						
1.	HV9341	Project Work (Phase-II)	0	0	24	**12**
		TOTAL	**0**	**0**	**24**	**12**

TOTAL CREDITS TO BE EARNED FOR THE AWARD THE DEGREE 20+20+15+12= 67

ELECTIVES FOR M.E HIGH VOLTAGE ENGINEERING

ELECTIVE I

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
1.	CL9312	System Theory	3	0	0	3
2.	PE9211	Analysis of Electrical machines	3	0	0	3
3.	ET9211	Advanced Digital System design	3	0	0	3

ELECTIVE II & III

4.	PS9223	Flexible AC Transmission Systems	3	0	0	3
5.	PE9261	Power Quality	3	0	0	3
6.	PE9224	Microcontroller and DSP based System Design	3	0	0	3
7.	PE9223	Special Electrical machines	3	0	0	3
8.	ET9272	Advanced Digital Signal Processing	3	0	0	3
9.	CL9321	Computer Aided Design of Instrumentation System	2	0	2	4

ELECTIVE IV, V & VI

10.	HV9351	Advanced Topics in High Voltage Engineering	3	0	0	3
11.	HV9352	Pollution Performance of Power Apparatus and Systems	3	0	0	3
12.	HV9353	Electromagnetic Interference and Electromagnetic Compatibility	3	0	0	3
13.	PS9275	High Voltage Direct Current Transmission	3	0	0	3
14.	PS9276	Wind Energy Conversion Systems	3	0	0	3
15.	CL9351	Soft Computing Techniques	3	0	0	3
16.	CL9358	System Identification and Adaptive Control	3	0	0	3
17.	CL9356	Optimal Control and Filtering	3	0	0	3
18.	ET9278	Applications of MEMS Technology	3	0	0	3

HV 9321 HIGH VOLTAGE TESTING TECHNIQUES L T P C
3 0 0 3

UNIT I INTRODUCTION 9

Objectives of high voltage testing, classification of testing methods- self restoration and non-self restoration systems-standards and specifications, measurement techniques Diagnostic testing-online measurement.

UNIT II STATISTICAL EVALUTION OF MEASURED RESULTS 9

Determination of probability values, Distribution function of a measured quantity, confidence limits of the mean values of disruptive discharges - 'Up and Down' method for determining the 50% disruptive discharge voltage, multi stress ageing, life data analysis

UNIT III TESTING TECHNIQUES FOR ELECTRICAL EQUIPMENT 9

Testing of insulators, bushings, air break switches, isolators, circuit breakers, power transformers-voltage transformers-current transformers, surge diverters, cable -testing methodology-recording of oscillograms - interpretation of test results

UNIT IV NON-DESTRUCTIVE INSULATION TEST TECHNIQUES 9

Dynamic properties of dielectrics-dielectric loss and capacitance measurement-partial discharge measurements-basic partial discharge(PD) circuit – PD currents- PD quantities -Digital PD instruments and measurements, acoustic emission technique and UHF Techniques for PD identification, Corona and RIV measurements on line hardware.

UNIT V POLLUTION TESTS AND DESIGN OF HIGH VOLTAGE LAB 9

Artificial Pollution tests- salt-fog method, solid layer method, Dimensions of High voltage laboratory, equipment- fencing ,earthing and shielding, circuits for high voltage experiments.

TOTAL : 45 PERIODS

REFERENCES

1. Diter Kind, Kurt Feser, "High voltage test techniques", SBA Electrical Engineering Series, New Delhi,1999.
2. Naidu M.S. and Kamaraju V., "High voltage Engineering", Tata McGraw Hill Publishing Company Ltd., New Delhi, 2004.
3. Kuffel, E., Zaengl, W.S. and Kuffel J., "High Voltage Engineering Fundamentals", Elsvier India P Ltd, 2005
4. Gallagher, T.J., and Pearmain A., "High Voltage Measurements, Testing and Design", John Willey & Sons, New York, 1983.
5. IS, IEC and IEEE standards for "Dielectric Testing of High Voltage Apparatus" W.Nelson, Applied Life Data Analysis, John Wiley and Sons, New York, 1982.
6. W.Kennedy, "Recommended Dielectric Tests and Test Procedures for Converter Transformer and Smoothing Reactors", IEEE Transactions on Power Delivery, Vol.1, No.3, pp 161-166, 1986.
7. IEC – 60270, "HV Test technique – Partial Discharge Mechanism", 3rd Edition December 2000.
8. M.D Judd, Liyang, Ian BB Hunter, "P.D Monitoring of Power Transformers using UHF Sensors" Vol.21, No.2, pp5-14, 2004.
9. M.D Judd, Liyang, Ian BB Hunter "P.D Monitoring of Power Transformers using UHF Sensors Part II, Vol.21, No.3, pp 5-13, 2004.

HV 9322 INSULATION DESIGN OF HIGH VOLTAGE POWER APPARATUS

L	T	P	C
3	0	0	3

UNIT I INTRODUCTION **9**

Basic arrangements of the insulation systems-factors affecting the performance of dielectric materials - Electric field distribution-utilization factor, field in homogeneous and multi-dielectric isotropic material

UNIT II DESIGN OF INSULATORS, BUSHINGS AND CAPACITORS **9**

Basic configurations, Classification based on insulating materials and application, design principles.

UNIT III INSULATION DESIGN OF POWER TRANSFORMERS **9**

Insulation schemes in transformer , design of transformer windings,surge phenomena in transformer windings-effect of series and shunt capacitance and stress control techniques.

UNIT IV DESIGN OF INSTRUMENT TRANSFORMERS AND CABLE JOINTS **9**

Classification based on insulating materials and design of potential and current transformers, Types of cable joints and terminations-capacitive grading- non-linear resistive grading.

UNIT V SURGE ARRESTER **9**

Types of surge arresters - gapped and gapless - electrical characteristics – housing materials - pollution performance - modeling of arrestor - insulation co-ordination.

TOTAL : 45 PERIODS

REFERENCES

1. Dieter Kind and Hermann Karner, “High Voltage insulation technology”, Translated from German by Y.Narayana Rao, Friedr. Vieweg & Sohn, Braunschweig, 1985.
2. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsvier India Pvt. Ltd, 2005
3. Alston, L.L, “High Voltage Technology”, Oxford University Press, London 1968.
4. Karsai, K.Kerenyi, D. and Kiss. L., “Large Power Transformers”, Elsevier, Armsterdam, 1987.
5. Feinberg, R., “Modern Power Transformer Practice”, The Macmillan Press Ltd., New York, 1979.
6. A.C.Franklin and J.S.C.Franklin, “The J & P Transformer Book”, Butterworth-Heinmann, New Delhi, 1995. Eleventh edition.
7. Minoo Mobedjina, Bengt Johnnerfelt, Lennart Stenstrom, “Design and testing of polymer – housed surge arrester”, GCC CIGRE 9th Symposium, 1998.
8. K.Steinfield, B.Krusha andW.Welsh, “Manufacturing and Application of Cage Design High Voltage Metaloxide Surge Arresters” XIII International Symposium on High Voltage Engineering, Netherland, 2003.
9. Dr.Ahmed Zahedi, “Effect of Day Band on Performance of UHV Surge Arrester and Leakage Current Monitoring using New Developed Model,” paper 7237, Proceedings of the 4th International Conference on Properties and Application of Dielectric Materials, 1994, Brishane Australia.

HV 9323 HIGH VOLTAGE SWITCHGEAR L T P C
3 0 0 3

UNIT I INTRODUCTION 9

Insulation of switchgear - coordination between inner and external insulation, Insulation clearances in air, oil, SF_6 and vacuum, bushing insulation, solid insulating materials – dielectric and mechanical strength consideration.

UNIT II CIRCUIT INTERRUPTION 9

Switchgear terminology – Arc characteristics – direct and alternating current interruption – arc quenching phenomena – computer simulation of arc models – transient re-striking voltage – RRRV-recovery voltage-current chopping-capacitive current breaking-auto re-closing.

UNIT III SHORTCIRCUIT CALCULATIONS AND RATING OF CIRCUITBREAKERS 9

Types of faults in power systems-short circuit current and short circuit MVA calculations for different types of faults-rating of circuit breakers – symmetrical and asymmetrical ratings.

UNIT IV TYPES OF CIRCUIT BREAKERS 9

Classification of circuit breakers-design, construction and operating principles of bulk oil, minimum oil, air blast, SF_6 and vacuum circuit breakers – Comparison of different types of circuit breakers.

UNIT V TESTING OF CIRCUIT BREAKERS 9

Type tests and routine tests – short circuit testing-synthetic testing of circuit breakers-recent advancements in high voltage circuit breakers.

TOTAL : 45 PERIODS

REFERENCES

1. Chunikhin, A. and Zhavoronkov, M., “High Voltage Switchgear Analysis and Design”, Mir Publishers, Moscow, 1989.
2. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsvier India Pvt. Ltd, 2005
3. Flursscheim, C.H. (Editor), “Power Circuit Breaker-Theory and Design”, IEE Monograph Series 17, Peter Peregrinus Ltd., Southgate House, Stevenage, Herts, SC1 1HQ, England, 1977.
4. Ananthakrishnan S and Guruprasad K.P., “Transient Recovery Voltage and Circuit Breakers”, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 1999.
5. Funio Nakanishi, “Switching Phenomena in High Voltage Circuit Breakers”, Marcel Dekker Inc., New York, 1991.

HV 9324 EHV POWER TRANSMISSION LT P C
3 0 0 3

UNIT I INTRODUCTION 9

Standard transmission voltages – different configurations of EHV and UHV lines – average values of line parameters – power handling capacity and line loss – costs of transmission lines and equipment – mechanical considerations in line performance.

UNIT II CALCULATION OF LINE PARAMETERS 9

Calculation of resistance, inductance and capacitance for multi-conductor lines – calculation of sequence inductances and capacitances – line parameters for different modes of propagation – resistance and inductance of ground return, numerical example involving a typical 400/220kV line using line constant program.

UNIT III VOLTAGE GRADIENTS OF CONDUCTORS 9

Charge-potential relations for multi-conductor lines – surface voltage gradient on conductors – gradient factors and their use – distribution of voltage gradient on sub conductors of bundle - voltage gradients on conductors in the presence of ground wires on towers.

UNIT IV CORONA EFFECTS 9

Power losses and audible losses: I^2R loss and corona loss - audible noise generation and characteristics - limits for audible noise - Day-Night equivalent noise level- radio interference**:** corona pulse generation and properties - limits for radio interference fields.

UNIT V ELECTROSTATIC FIELD OF EHV LINES 9

Effect of EHV line on heavy vehicles - calculation of electrostatic field of AC lines- effect of high field on humans, animals, and plants - measurement of electrostatic fields - electrostatic Induction in unenergised circuit of a D/C line - induced voltages in insulated ground wires - electromagnetic interference.

TOTAL : 45 PERIODS

REFERENCES

1. Rakosh Das Begamudre, “Extra High Voltage AC Transmission Engineering”, Second Edition, New Age International Pvt. Ltd., 1990.
2. Power Engineer’s Handbook, Revised and Enlarged 6th Edition, TNEB Engineers’ Association, October 2002.
3. Microtran Power System Analysis Corporation, Microtran Reference Manual, Vancouver Canada. (Website: www.microtran.com).

HV 9325 HIGH VOLTAGE LABORATORY LT P C
0 0 3 2

1. High voltage AC measurement.
2. High voltage DC measurement.
3. High Impulse voltage measurement.
4. Study of break down phenomena in air, oil and solid dielectrics under uniform and non-uniform electrode configurations.

5. Capacitance and loss tangent measurement.
6. Partial discharge measurement.
7. Measurement of Earth resistance.
8. Measurement of resonant frequencies and internal voltage distribution in transformer windings.
9. Electromagnetic field measurement using field meter.
10. Measurement of harmonics using Energy analyzer.

TOTAL : 45 PERIODS

HV 9331	**PROJECT WORK (PHASE I)**	**0**	**0**	**12**	**6**
HV 9341	**PROJECT WORK (PHASE – II)**	**0**	**0**	**24**	**12**

CL9312 SYSTEM THEORY L T P C
3 0 0 3

UNIT I STATE VARIABLE REPRESENTATION 9

Introduction-Concept of State-State equation for Dynamic Systems-Time invariance and linearity-Nonuniqueness of state model-State Diagrams-Physical System and State Assignment.

UNIT II SOLUTION OF STATE EQUATION 9

Existence and uniqueness of solutions to Continuous-time state equations-Solution of Nonlinear and Linear Time Varying State equations-Evaluation of matrix exponential-System modes-Role of Eigenvalues and Eigenvectors.

UNIT III CONTROLLABILITY AND OBSERVABILITY 9

Controllability and Observability-Stabilizability and Detectability-Test for Continuous time Systems- Time varying and Time invariant case-Output Controllability-Reducibility-System Realizations.

UNIT IV STABILTY 9

Introduction-Equilibrium Points-Stability in the sense of Lyapunov-BIBO Stability-Stability of LTI Systems-Equilibrium Stability of Nonlinear Continuous Time Autonomous Systems-The Direct Method of Lyapunov and the Linear Continuous-Time Autonomous Systems-Finding Lyapunov Functions for Nonlinear Continuous Time Autonomous Systems-Krasovskii and Variable-Gradiant Method.

UNIT V MODAL CONTROL 9

Introduction-Controllable and Observable Companion Forms-SISO and MIMO Systems-The Effect of State Feedback on Controllability and Observability-Pole Placement by State Feedback for both SISO and MIMO Systems-Full Order and Reduced Order Observers.

TOTAL : 45 PERIODS

REFERENCES:
1. M. Gopal, “Modern Control System Theory”, New Age International, 2005.
2. K. Ogatta, “Modern Control Engineering”, PHI, 2002.
3. John S. Bay, “Fundamentals of Linear State Space Systems”, McGraw-Hill, 1999.
4. D. Roy Choudhury, “Modern Control Systems”, New Age International, 2005.
5. John J. D’Azzo, C. H. Houpis and S. N. Sheldon, “Linear Control System Analysis and Design with MATLAB”, Taylor Francis, 2003.
6. Z. Bubnicki, ”Modern Control Theory”, Springer, 2005.

PE 9211 ANALYSIS OF ELECTRICAL MACHINES L T P C
3 0 0 3

UNIT I PRINCIPLES OF ELECTROMAGNETIC ENERGY CONVERSION 9

General expression of stored magnetic energy, co-energy and force/ torque – example using single and doubly excited system –Calculation of air gap mmf and per phase machine inductance using physical machine data.

UNIT II REFERENCE FRAME THEORY 9

Static and rotating reference frames – transformation of variables – reference frames – transformation between reference frames – transformation of a balanced set –balanced steady state phasor and voltage equations – variables observed from several frames of reference.

UNIT III DC MACHINES 9

Voltage and toque equations – dynamic characteristics of permanent magnet and shunt DC motors – state equations - solution of dynamic characteristic by Laplace transformation.

UNIT IV INDUCTION MACHINES 9

Voltage and toque equations – transformation for rotor circuits – voltage and toque equations in reference frame variables – analysis of steady state operation – free acceleration characteristics – dynamic performance for load and torque variations – dynamic performance for three phase fault – computer simulation in arbitrary reference frame.

UNIT V SYNCHRONOUS MACHINES 9

Voltage and Torque Equation – voltage Equation in arbitrary reference frame and rotor reference frame – Park equations - **rotor angle and angle between rotor** – steady state analysis – dynamic performances for torque variations- dynamic performance for three phase fault – transient stability limit – critical clearing time – computer simulation.

TOTAL : 45 PERIODS

TEXT BOOKS
1. Paul C.Krause, OlegWasyzczuk, Scott S, Sudhoff, “Analysis of Electric Machinery and Drive Systems”, IEEE Press, Second Edition.
2. R.Krishnan, “Electric Motor Drives, Modeling, Analysis and Control” , Prentice Hall of India, 2002

REFERENCES
1. Samuel Seely, " Eletomechanical Energy Conversion", Tata McGraw Hill Publishing Company,
2. A.E, Fitzgerald, Charles Kingsley, Jr, and Stephan D, Umanx, " Electric Machinery", Tata McGraw Hill, 5th Edition, 1992

ET 9211 ADVANCED DIGITAL SYSTEM DESIGN L T P C
3 0 0 3

AIM

To expose the students to the fundamentals of digital logic based system design**.**

OBJECTIVES

To impart knowledge on

- Basics on Synchronous & Async digital switching design.
- Design & realisation of error free functional blocks for digital systems

UNIT I SEQUENTIAL CIRCUIT DESIGN 9

Analysis of Clocked Synchronous Sequential Networks (CSSN) Modelling of CSSN – State Stable Assignment and Reduction – Design of CSSN – Design of Iterative Circuits – ASM Chart – ASM Realization, Design of Arithmetic circuits for Fast adder- Array Multiplier.

UNIT II ASYNCHRONOUS SEQUENTIAL CIRCUIT DESIGN 9

Analysis of Asynchronous Sequential Circuit (ASC) – Flow Table Reduction – Races in ASC – State Assignment Problem and the Transition Table – Design of ASC – Static and Dynamic Hazards – Essential Hazards – Data Synchronizers – Designing Vending Machine Controller – Mixed Operating Mode Asynchronous Circuits.

UNIT III FAULT DIAGNOSIS AND TESTABILITY ALGORITHMS 9

Fault Table Method – Path Sensitization Method – Boolean Difference Method – Kohavi Algorithm – Tolerance Techniques – The Compact Algorithm – Practical PLA's – Fault in PLA – Test Generation – Masking Cycle – DFT Schemes – Built-in Self Test.

UNIT IV SYNCHRONOUS DESIGN USING PROGRAMMABLE DEVICES 9

Programming Techniques -Re-Programmable Devices Architecture- Function blocks, I/O blocks, Interconnects, Realize combinational, Arithmetic, Sequential Circuit with Programmable Array Logic; Architecture and application of Field Programmable Logic Sequence.

UNIT V NEW GENERATION PROGRAMMABLE LOGIC DEVICES 9

Foldback Architecture with GAL, EPLD, EPLA , PEEL, PML; PROM – Realization State machine using PLD – FPGA – Xilinx FPGA – Xilinx 2000 - Xilinx 3000

TOTAL : 45 PERIODS

REFERENCES:
1. Donald G. Givone, “Digital principles and Design”, Tata McGraw Hill 2002.
2. Stephen Brown and Zvonk Vranesic, “Fundamentals of Digital Logic with VHDL Deisgn”, Tata McGraw Hill, 2002
3. Mark Zwolinski, “Digital System Design with VHDL”, Pearson Education, 2004
4. Parag K Lala, “Digital System design using PLD”, BS Publications, 2003
5. John M Yarbrough, “Digital Logic applications and Design”, Thomson Learning, 2001
6. Nripendra N Biswas, “Logic Design Theory”, Prentice Hall of India, 2001
7. Charles H. Roth Jr., “Fundamentals of Logic design”, Thomson Learning, 2004.

PS 9223 FLEXIBLE AC TRANSMISSION SYSTEMS L T P C
3 0 0 3

UNIT I INTRODUCTION 9

Reactive power control in electrical power transmission lines -Uncompensated transmission line - series compensation – Basic concepts of static Var Compensator (SVC) – Thyristor Switched Series capacitor (TCSC) – Unified power flow controller (UPFC).

UNIT II STATIC VAR COMPENSATOR (SVC) AND APPLICATIONS 9

Voltage control by SVC – Advantages of slope in dynamic characteristics – Influence of SVC on system voltage – Design of SVC voltage regulator –Modelling of svc for power flow and transient stability – Applications: Enhancement of transient stability – Steady state power transfer – Enhancement of power system damping – Prevention of voltage instability.

UNIT III THYRISTOR CONTROLLED SERIES CAPACITOR (TCSC) AND APPLICATIONS 9

Operation of the TCSC – Different modes of operation – Modelling of TCSC – Variable reactance model – Modelling for Power Flow and stability studies. Applications: Improvement of the system stability limit – Enhancement of system damping-SSR Mitigation.

UNIT IV VOLTAGE SOURCE CONVERTER BASED FACTS CONTROLLERS 9

Static Synchronous Compensator (STATCOM) – Principle of operation – V-I Characteristics. Applications: Steady state power transfer-Enhancement of transient stability - Prevention of voltage instability. SSSC-operation of SSSC and the control of power flow –Modelling of SSSC in load flow and transient stability studies. Applications: SSR Mitigation-UPFC and IPFC

UNIT V CO-ORDINATION OF FACTS CONTROLLERS 9

Controller interactions – SVC – SVC interaction – Co-ordination of multiple controllers using linear control techniques – Control coordination using genetic algorithms.

TOTAL : 45 PERIODS

REFERENCES

1. R.Mohan Mathur, Rajiv K.Varma, "Thyristor – Based Facts Controllers for Electrical Transmission Systems", IEEE press and John Wiley & Sons, Inc.
2. Narain G. Hingorani, "Understanding FACTS -Concepts and Technology of Flexible AC Transmission Systems", Standard Publishers Distributors, Delhi- 110 006
3. K.R.Padiyar," FACTS Controllers in Power Transmission and Distribution", New Age International(P) Limited, Publishers, New Delhi, 2008
4. A.T.John, "Flexible A.C. Transmission Systems", Institution of Electrical and Electronic Engineers (IEEE), 1999.
5. V.K.Sood,HVDC and FACTS controllers – Applications of Static Converters in Power System, APRIL 2004 , Kluwer Academic Publishers.

PE 9261 POWER QUALITY L T P C
3 0 0 3

UNIT I INTRODUCTION 9

Introduction – Characterisation of Electric Power Quality: Transients, short duration and long duration voltage variations, Voltage imbalance, waveform distortion, Voltage fluctuations, Power frequency variation, Power acceptability curves – power quality problems: poor load power factor, Non linear and unbalanced loads, DC offset in loads, Notching in load voltage, Disturbance in supply voltage – Power quality standards.

UNIT II NON-LINEAR LOADS 9

Single phase static and rotating AC/DC converters, Three phase static AC/DC converters, Battery chargers, Arc furnaces, Fluorescent lighting, pulse modulated devices, Adjustable speed drives.

UNIT III MEASUREMENT AND ANALYSIS METHODS 9

Voltage, Current, Power and Energy measurements, power factor measurements and definitions, event recorders, Measurement Error – Analysis: Analysis in the periodic steady state, Time domain methods, Frequency domain methods: Laplace's, Fourier and Hartley transform – The Walsh Transform – Wavelet Transform.

UNIT IV ANALYSIS AND CONVENTIONAL MITIGATION METHODS 9

Analysis of power outages, Analysis of unbalance: Symmetrical components of phasor quantities, Instantaneous symmetrical components, Instantaneous real and reactive powers, Analysis of distortion: On–line extraction of fundamental sequence components from measured samples – Harmonic indices – Analysis of voltage sag: Detorit Edison sag score, Voltage sag energy, Voltage Sag Lost Energy Index (VSLEI)- Analysis of voltage flicker, Reduced duration and customer impact of outages, Classical load balancing problem: Open loop balancing, Closed loop balancing, current balancing, Harmonic reduction, Voltage sag reduction.

UNIT V POWER QUALITY IMPROVEMENT 9

Utility-Customer interface –Harmonic filters: passive, Active and hybrid filters –Custom power devices: Network reconfiguring Devices, Load compensation using DSTATCOM, Voltage regulation using DSTATCOM, protecting sensitive loads using DVR, UPQC – control strategies: P-Q theory, Synchronous detection method – Custom power park – Status of application of custom power devices.

TOTAL: 45 PERIODS

TEXT BOOKS

1. Arindam Ghosh "Power Quality Enhancement Using Custom Power Devices", Kluwer Academic Publishers, 2002
2. G.T.Heydt, "Electric Power Quality", Stars in a Circle Publications, 1994(2nd edition)
3. Power Quality - R.C. Duggan
4. Power system harmonics –A.J. Arrillga
5. Power electronic converter harmonics –Derek A. Paice

PE 9224	MICROCONTROLLER AND DSP BASED SYSTEM DESIGN	LT P C 3 0 0 3

UNIT I PIC 16C7X MICROCONTROLLER 9

Architecture memory organization – Addressing modes – Instruction set – Programming techniques – simple programs

UNIT II PERIPHERALS OF PIC 16C7X 9

Timers – interrupts – I/O ports – I^2C bus for peripheral chip access – A/D converter – UART

UNIT III MOTOR CONTROL SIGNAL PROCESSORS 9

Introduction- System configuration registers - Memory Addressing modes - Instruction set – Programming techniques – simple programs

UNIT IV PERIPHERALS OF SIGNAL PROCESSORS 9

General purpose Input/Output (GPIO) Functionality- Interrupts - A/D converter-Event Managers (EVA, EVB)- PWM signal generation

UNIT V APPLICATIONS OF PIC AND SIGNAL PROCESSORS 9

Voltage regulation of DC-DC converters- Stepper motor and DC motor control- Clarke's and parks transformation-Space vector PWM- Control of Induction Motors and PMSM.

TOTAL : 45 PERIODS

TEXT BOOKS:

1. John B.Peatman , 'Design with PIC Microcontrollers,' Pearson Education, Asia 2004
2. Hamid A.Toliyat, Steven Campbell, 'DSP based electromechanical motion control', CRC Press

PE 9223	SPECIAL ELECTRICAL MACHINES	LT P C 3 0 0 3

UNIT I STEPPING MOTOR 9

Constructional features – Principle of operation – Modes of excitation – Torque production in variable reluctance stepping motor - Dynamic characteristics – Drive systems and circuit for open loop control – Closed loop control of stepping motor.

UNIT II SWITCHED RELUCTANCE MOTORS 9

Constructional features – principle of operation – Torque equation – Power controllers – Characteristics and control microprocessor based controller.

UNIT III SYNCHRONOUS RELUCTANCE MOTORS 9

Constructional features: axial and radial air gap Motors – Operating principle – Reluctance torque – phasor diagram –motor characteristics.

UNIT IV PERMANENT MAGNET SYNCHRONOUS MOTROS 9

Principle of operation –EMF –Power input and torque expressions –Phasor diagram – power controller-Torque speed characteristics-Self control –Vector control –current control schemes.

UNIT V PERMANENT MAGNET BRUSHLESS DC MOTORS 9

Commutation in DC motors, Difference between mechanical and electronic commutators- Hall sensors, Optical sensors - Multiphase Brushless motor –Square wave permanent magnet brushless motor drives –Torque and emf equation-Torque speed characteristics-Controllers –Microprocessors based controller

TOTAL : 45 PERIODS

REFERENCES

1. Miller, T.J.E. “Brushless permanent magnet and reluctance motor drives”,Clarendon Press, Oxford,1989.
2. Kenjo, T, “Stepping motors and their microprocessor control ”,Clarendon Press,Oxford 1989.
3. R.Krishnan, “Switched Reluctance Motors Drives: Modelling, Simulation, Analysis Design and Applications”, CRC Press, New York, 2001.

ET 9272 ADVANCED DIGITAL SIGNAL PROCESSING L T P C

3 0 0 3

UNIT I INTRODUCTION 9

Mathematical description of change of sampling rate – Interpolation and Decimation, Filter implementation for sampling rate conversion – direct form FIR structures, DTFT, FFT, Wavelet transform and filter bank implementation of wavelet expansion of signals

UNIT II STIMATION AND PREDICTION TECHNIQUES 9

Discrete Random Processes – Ensemble averages, Stationary processes, Autocorrelation and Auto covariance matrices. Parseval’s Theorem, Wiener-Khintchine Relation – Power Spectral Density**.** AR, MA, ARMA model based spectral estimation. Parameter Estimation, Linear prediction – Forward and backward predictions, Least mean squared error criterion – Wiener filter for filtering and prediction, Discrete Kalman filter.

UNIT III DIGITAL SIGNAL PROCESSOR 9

Basic Architecture – Computational building blocks, MAC, Bus Architecture and memory, Data Addressing, Parallelism and pipelining, Parallel I/O interface, Memory Interface, Interrupt, DMA.

UNIT IV APPLICATION OF DSP 9

Design of Decimation and Interpolation Filter, FFT Algorithm, PID Controller, Application for Serial Interfacing, DSP based Power Meter, Position control.

UNIT V VLSI IMPLEMENTATION 9

Basics on DSP sytem architecture design using VHDL programming, Mapping of DSP algorithm onto hardware, Realisation of MAC & Filter structure.

TOTAL: 45 PERIODS

REFERENCES:

1. Bernard Widrow, Samuel D. Stearns, “Adaptive Signal Processing”, Pearson Education, third edition, 2004.
2. Dionitris G. Manolakis, Vinay K. Ingle, Stepen M. Kogon,”Statistical & Adaptive signal processing, spectral estimation, signal modeling, Adaptive filtering & Array processing”, McGraw-Hill International edition 2000.
3. Monson H. Hayes, “Statistical Digital Signal Processing and Modelling”, John Wiley and Sons, Inc.,
4. John G. Proaks, Dimitris G. Manolakis, “Digital Signal Processing”, Pearson Education 2002.
5. S. Salivahanan, A. Vallavaraj and C. Gnanapriya “Digital Signal Processing”, TMH,2000.
6. Avatar Sing, S. Srinivasan, “Digital Signal Processing- Implementation using DSP Microprocessors with Examples from TMS320C54xx”, Thomson India, 2004.
7. Lars Wanhammer, “DSP Integrated Circuits”, Academic press, 1999,New York.
8. Ashok Ambardar,”Digital Signal Processing: A Modern Introduction”,Thomson India edition, 2007.
9. Lars Wanhammer, “DSP Integrated Circuits”, Academic press, 1999,New York.

CL9321	COMPUTER AIDED DESIGN OF INSTRUMENTATION SYSTEMS	L T P C 2 0 2 4

UNIT I DATA ACQUISITION AND INSTRUMENT INTERFACE 9

Programming and simulation of Building block of instrument Automation system – Signal analysis, I/O port configuration with instrument bus protocols - ADC, DAC, DIO, counters & timers, PC hardware structure, timing, interrupts, DMA, software and hardware installation, current loop, RS 232/RS485, GPIB, USB protocols,

UNIT II VIRTUAL INSTRUMENTATION PROGRAMMING TECHNIQUES 9

Block diagram and architecture of a virtual instrument, Graphical programming in data flow, comparison with conventional programming, Vis and sub-Vis, loops and charts, arrays, clusters and graphs, case and sequence structures, formula nodes, local and global variables, string and file I/O.

UNIT III DESIGN TEST & ANALYSIS 9

Spectral estimation using Fourier Transform, power spectrum, correlation methods, Stability analysis, Fault analysis –Sampling, Data Parity and error coding checks,

Synchronization testing – Watch dog timer, DMA method – Real-time Clocking, Noise-Gaussian, White analysis

UNIT IV PC BASED INSTRUMENTATION 9

Introduction – Evolution of signal standard – HART Communication protocol – Communication modes – HART networks – control system interface – HART commands – HART field controller implementation – HART and the OSI model

UNIT V SIMULATION OF PHYSICAL SYSTEMS 9

Simulation of linear & Non-linear models of systems, Hardware in loop simulation of physical systems using special softwares.

L=30, P=30, TOTAL= 60 PERIODS

REFERENCES:

1. K. Ogatta, “Modern control Engineering”, Fourth edition, Perason education 2002.
2. Dorf and Bishop, “Modern Control Engineering”, Addison Weseley, 1998.
3. Patrick H. Garrett,” High performance Instrumentation and Automation”, CRC Press, Taylor & Francis Group, 2005.
4. MAPLE V programming guide
5. MATLAB/SIMULINK user manual
6. MATHCAD/VIS SIM user manual.
7. LABVIEW simulation user manual

HV9351 ADVANCED TOPICS IN HIGH VOLTAGE ENGINEERING L T P C
3 0 0 3

UNIT I MEASUREMENT AND DIAGNOSTIC TECHNOLOGIES 9

Introduction – Digital Impulse Recorders – Digital Techniques in HV tests – Testing automation – Electric field measurement – Electro-optic Sensors- Magneto-optic Sensors – Measurement of very fast transients in GIS – Space charge measurement techniques – electro-optical imaging techniques.

UNIT II APPLICATION OF HIGH VOLTAGE ENGINEERING IN INDUSTRY 9

Introduction – electrostatic applications- electrostatic precipitation, separation , painting / coating, spraying ,imaging ,printing ,Transport of materials – Sandpaper Manufacture – Smoke particle detector – Electrostatic spinning ,pumping , propulsion – Ozone generation – Biomedical applications.

UNIT III SAFETY AND ELECTROSTATIC HAZARDS 9

Introduction – Nature of static electricity – Triboelectric series – Basic laws of Electrostatic electricity– materials and static electricity – Electrostatic discharges (ESD) – Static electricity problems – Hazards of Electrostatic electricity in industry – Hazards from electrical equipment and installations – Static eliminators and charge neutralizers – Lightning protection.

UNIT IV PULSED ELECTRIC FIELDS 9

Introduction-definitions, descriptions and applications-mechanisms of microbial in-activations-electrical breakdown-electroporation-inactivation models -Critical factors-

analysis of process, product and microbial factors-pulse generators and treatment chamber design-Research needs.

UNIT V APPLICATION OF PEF TECHNOLOGY IN FOOD PRESERVATION 9

Processing of juices, milk, egg, meat and fish products- Processing of water and waste. Industrial feasibility, cost and efficiency analysis.

TOTAL : 45 PERIODS

REFERENCES

1. N.H.Malik, A.A.Ai-Arainy, M.I.Qureshi, “Electrical Insulation in power systems”, Marcel Dekker, inc., 1998.
2. Mazen Abdel-Salam, Hussien Anis, Ahdab EI-Morshedy, “High Voltage Engineering”, Second Edition, Theory and Practice, Marcel Dekker, Inc. 2000,
3. John D.Kraus, Daniel A.Fleisch, “Electromagnetics with Applications” McGraw Hill International Editions, 1992.
4. Shoait Khan, “ Industrial Power System”, CRC Press, Taylor & Francis group, 2008.
5. G.V. Barbosa –Canovas , “Pulsed electric fields in food processing:Fundamental aspects and applications” CRC Publisher Edition March 1 2001.
6. H L M Lelieveld and Notermans.S,et.al., “Food preservation by pulsed electric fields: From research to application”, Woodhead Publishing Ltd. October 2007.

HV9352	POLLUTION PERFORMANCE OF POWER APPARATUS AND SYSTEMS	L T P C 3 0 0 3

UNIT I INTRODUCTION 9

Fundamental process of pollution flashover – development and effect of contamination layer – creepage distance – pollution conductivity – mechanism of pollution flashover – analytical determination of flashover voltage.

UNIT II POLLUTION TESTING 9

Artificial pollution testing – salt-fog method – solid layer method – monitoring of parameters – measurement of layer conductivity – field testing methods.

UNIT III POLLUTION PERFORMANCE OF INSULATORS 9

Ceramic and non-ceramic insulators – design of shed profiles – rib factor effect in AC and DC insulators – modeling.

UNIT IV POLLUTION PERFORMANCE OF SURGE DIVERTERS 9

External insulation – effect of pollution on the protective characteristics of gap and gapless arresters – modeling of surge diverters under polluted conditions.

UNIT V POLLUTION PERFORMANCE OF INDOOR EQUIPMENT 9

Condensation and contamination of indoor switch gear – performance of organic insulator under polluted conditions – accelerated testing techniques.

TOTAL : 45 PERIODS

REFERENCES
1. Kind and Karner, “High Voltage Insulation”, Translated from German by Y.Narayana Rao, Frider. Vieweg, & Sohn, Braunschweig, Weishaden, 1985.
2. Kuffel, E., Zaengl, W.S. and Kuffel J., “High Voltage Engineering Fundamentals”, Elsvier India Pvt. Ltd, 2005.
3. Klaus Ragaller, “Surges in High Voltage Networks”, Plenum Press, New York, 1980.
4. Looms, J.S.T., “Insulators for High Voltages”, Peter Peregrinus Ltd., London, 1988.
5. Dieter Kind and Kurt Feser, “High Voltage Test Techniques”, Second Edition, SBA Electrical Engineering Series, New Delhi, 1999.
6. Ravi S. Gorur “Outdoor Insulators”, Inc. Phoenix, Arizona 85044, USA, 1999.

HV9353 ELECTROMAGNETIC INTERFERENCE AND ELECTROMAGNETIC COMPATIBILITY **L T P C 3 0 0 3**

UNIT I INTRODUCTION **9**

Sources of EMI, Conducted and radiated interference- Characteristics - Designing for electromagnetic compatibility (EMC)- EMC regulation- typical noise path- use of network theory- methods of eliminating interferences.

UNIT II METHOD OF HARDENING **9**

Cabling –capacitive coupling- inductive coupling- shielding to prevent magnetic radiation- shield transfer impedance, Grounding – safety grounds – signal grounds- single point and multipoint ground systems- hybrid grounds- functional ground layout – grounding of cable shields- ground loops-guard shields.

UNIT III BALANCING, FILTERING AND SHIELDING **9**

Power supply decoupling- decoupling filters-amplifier filtering –high frequency filtering- shielding – near and far fields- shielding effectiveness- absorption and reflection loss, Shielding with magnetic material- conductive gaskets, windows and coatings- grounding of shields.

UNIT IV DIGITAL CIRCUIT NOISE AND LAYOUT **9**

Frequency versus time domain- analog versus digital circuits- digital logic noise- internal noise sources- digital circuit ground noise –power distribution-noise voltage objectives-measuring noise voltages-unused inputs-logic families.

UNIT V ELECTROSTATIC DISCHARGE,STANDARDS AND LABORATORY TECHNIQUES **9**

Static Generation- human body model- static discharges-ED protection in equipment design- ESD versus EMC, Industrial and Government standards – FCC requirements – CISPR recommendations-Laboratory techniques- Measurement methods for field strength-EMI.

TOTAL : 45 PERIODS

REFERENCES

1. Henry W.Ott, " Noise reduction techniques in electronic systems", John Wiley & Sons, 1989.
2. Bernhard Keiser, "Principles of Electro-magnetic Compatibility", Artech House, Inc. (685 canton street, Norwood, MA 020062 USA) 1987.
3. Bridges, J.E Milleta J. and Ricketts.L.W., "EMP Radiation and Protective techniques", John Wiley and sons, USA 1976.
4. IEEE National Symposium on "Electromagnetic Compatibility", IEEE, 445, hoes Lane, Piscataiway, NJ 08855.

PS 9275 HIGH VOLTAGE DIRECT CURRENT TRANSMISSION L T P C
3 0 0 3

UNIT I DC POWER TRANSMISSION TECHNOLOGY 6

Introduction - Comparison of AC and DC transmission **–** Application of DC transmission – Description of DC transmission system - Planning for HVDC transmission **–** Modern trends in DC transmission – DC breakers – Cables, VSC based HVDC.

UNIT II ANALYSIS OF HVDC CONVERTERS AND HVDC SYSTEM CONTROL 12

Pulse number, choice of converter configuration **–** Simplified analysis of Graetz circuit - Converter bridge characteristics – characteristics of a twelve pulse converter- detailed analysis of converters. General principles of DC link control **–** Converter control characteristics **–** System control hierarchy - Firing angle control **–** Current and extinction angle control **–** Generation of harmonics and filtering - power control **–** Higher level controllers.

UNIT III MULTITERMINAL DC SYSTEMS 9

Introduction **–** Potential applications of MTDC systems - Types of MTDC systems - Control and protection of MTDC systems - Study of MTDC systems.

UNIT IV POWER FLOW ANALYSIS IN AC/DC SYSTEMS 9

Per unit system for DC Quantities - Modelling of DC links - Solution of DC load flow - Solution of AC-DC power flow - Case studies.

UNIT V SIMULATION OF HVDC SYSTEMS 9

Introduction **–** System simulation: Philosophy and tools **–** HVDC system simulation **–** Modeling of HVDC systems for digital dynamic simulation – Dynamic intraction between DC and AC systems.

TOTAL : 45 PERIODS

REFERENCES:

1. K.R.Padiyar, , "HVDC Power Transmission Systems", New Age International (P) Ltd., New Delhi, 2002.
2. J.Arrillaga, , "High Voltage Direct Current Transmission", Peter Pregrinus, London, 1983.
3. P. Kundur, "Power System Stability and Control", McGraw-Hill, 1993.
4. Erich Uhlmann, " Power Transmission by Direct Current", BS Publications, 2004.
5. V.K.Sood,HVDC and FACTS controllers – Applications of Static Converters in Power System, APRIL 2004 , Kluwer Academic Publishers.

PS9276 WIND ENERGY CONVERSION SYSTEMS L T P C
3 0 0 3

UNIT I INTRODUCTION 9
Components of WECS-WECS schemes-Power obtained from wind-simple momentum theory-Power coefficient-Sabinin's theory-Aerodynamics of Wind turbine

UNIT II WIND TURBINES 9
HAWT-VAWT-Power developed-Thrust-Efficiency-Rotor selection-Rotor design considerations-Tip speed ratio-No. of Blades-Blade profile-Power Regulation-yaw control-Pitch angle control-stall control-Schemes for maximum power extraction.

UNIT III FIXED SPEED SYSTEMS 9
Generating Systems- Constant speed constant frequency systems -Choice of Generators-Deciding factors-Synchronous Generator-Squirrel Cage Induction Generator- Model of Wind Speed- Model wind turbine rotor - Drive Train model-Generator model for Steady state and Transient stability analysis.

UNIT IV VARIABLE SPEED SYSTEMS 9
Need of variable speed systems-Power-wind speed characteristics-Variable speed constant frequency systems synchronous generator- DFIG- PMSG -Variable speed generators modeling - Variable speed variable frequency schemes.

UNIT V GRID CONNECTED SYSTEMS 9
Stand alone and Grid Connected WECS system-Grid connection Issues-Machine side & Grid side controllers-WECS in various countries

TOTAL : 45 PERIODS

REFERENCES

1. L.L.Freris "Wind Energy conversion Systems", Prentice Hall, 1990
2. Ion Boldea, "Variable speed generators", Taylor & Francis group, 2006.
3. E.W.Golding "The generation of Electricity by wind power", Redwood burn Ltd., Trowbridge,1976.
4. S.Heir "Grid Integration of WECS", Wiley 1998.

CL9351 SOFT COMPUTING TECHNIQUES L T P C

3 0 0 3

UNIT I INTRODUCTION 9
Approaches to intelligent control. Architecture for intelligent control. Symbolic reasoning system, rule-based systems, the AI approach. Knowledge representation. Expert systems.

UNIT II ARTIFICIAL NEURAL NETWORKS 9

Concept of Artificial Neural Networks and its basic mathematical model, McCulloch-Pitts neuron model, simple perceptron, Adaline and Madaline, Feed-forward Multilayer Perceptron. Learning and Training the neural network. Data Processing: Scaling, Fourier transformation, principal-component analysis and wavelet transformations. Hopfield network, Self-organizing network and Recurrent network. Neural Network based controller

UNIT III FUZZY LOGIC SYSTEM 9

Introduction to crisp sets and fuzzy sets, basic fuzzy set operation and approximate reasoning. Introduction to fuzzy logic modeling and control. Fuzzification, inferencing and defuzzification. Fuzzy knowledge and rule bases. Fuzzy modeling and control schemes for nonlinear systems. Self-organizing fuzzy logic control. Fuzzy logic control for nonlinear time-delay system.

UNIT IV GENETIC ALGORITHM 9

Basic concept of Genetic algorithm and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using genetic algorithm. Concept on some other search techniques like tabu search and anD-colony search techniques for solving optimization problems.

UNIT V APPLICATIONS 9

GA application to power system optimisation problem, Case studies: Identification and control of linear and nonlinear dynamic systems using Matlab - Neural Network toolbox. Stability analysis of Neural-Network interconnection systems. Implementation of fuzzy logic controller using Matlab fuzzy-logic toolbox. Stability analysis of fuzzy control systems.

TOTAL : 45 PERIODS

REFERENCES

1. Jacek.M.Zurada, "Introduction to Artificial Neural Systems", Jaico Publishing House, 1999.
2. KOSKO,B. "Neural Networks And Fuzzy Systems", Prentice-Hall of India Pvt. Ltd., 1994.
3. KLIR G.J. & FOLGER T.A. "Fuzzy sets, uncertainty and Information", Prentice-Hall of India Pvt. Ltd., 1993.
4. Zimmerman H.J. "Fuzzy set theory-and its Applications"-Kluwer Academic Publishers, 1994.
5. Driankov, Hellendroon, "Introduction to Fuzzy Control", Narosa Publishers.

CL9358 SYSTEM IDENTIFICATION AND ADAPTIVE CONTROL L T P C

3 0 0 3

UNIT I MODELS FOR INDENTIFICATION 9

Models of LTI systems: Linear Models-State space Models-OE model- Model sets, Structures and Identifiability-Models for Time-varying and Non-linear systems: Models with Nonlinearities – Non-linear state-space models-Black box models, Fuzzy models'.

UNIT II NON-PARAMETRIC AND PARAMETRIC IDENTIFICATON 9

Transient response and Correlation Analysis – Frequency response analysis – Spectral Analysis – Least Square – Recursive Least Square –Forgetting factor- Maximum Likelihood – Instrumental Variable methods.

UNIT III NON-LINEAR IDENTIFICATION AND MODEL VALIDATION 9

Open and closed loop identification: Approaches – Direct and indirect identification – Joint input-output identification – Non-linear system identification – Wiener models – Power series expansions - State estimation techniques – Non linear identification using Neural Network and Fuzzy Logic.

UNIT IV ADAPTIVE COTROL AND ADAPTATION TECHNIQUES 9

Introduction – Uses – Auto tuning – Self Tuning Regulators (STR) – Model Reference Adaptive Control (MRAC) – Types of STR and MRAC – Different approaches to self-tuning regulators – Stochastic Adaptive control – Gain Scheduling

UNIT V CASE STUDIES 9

Inverted Pendulum, Robot arm, process control application: heat exchanger, Distillation column, application to power system, Ship steering control.

TOTAL : 45 PERIODS

REFERENCES:

1. Ljung," System Identification Theory for the User", PHI, 1987.
2. Torsten Soderstrom, Petre Stoica, "System Identification", prentice Hall ` International (UK) Ltd,1989.
3. Astrom and Wittenmark," Adaptive Control ", PHI
4. William S. Levine, " Control Hand Book".
5. Narendra and Annasamy," Stable Adaptive Control Systems, Prentice Hall, 1989.

CL9356 OPTIMAL CONTROL AND FILTERING L T P C
3 0 0 3

UNIT I INTRODUCTION 9

Statement of optimal control problem – Problem formulation and forms of optimal Control – Selection of performance measures. Necessary conditions for optimal control – Pontryagin's minimum principle – State inequality constraints – Minimum time problem.

UNIT II LQ CONTROL PROBLEMS AND DYNAMIC PROGRAMMING 9

Linear optimal regulator problem – Matrix Riccatti equation and solution method – Choice of weighting matrices – Steady state properties of optimal regulator – Linear tracking problem – LQG problem – Computational procedure for solving optimal control problems – Characteristics of dynamic programming solution – Dynamic programming application to discrete and continuous systems – Hamilton Jacobi Bellman equation.

UNIT III NUMERICAL TECHNIQUES FOR OPTIMAL CONTROL 9

Numerical solution of 2-point boundary value problem by steepest descent and Fletcher Powell method solution of Ricatti equation by negative exponential and interactive Methods

UNIT IV FILTERING AND ESTIMATION 9

Filtering – Linear system and estimation – System noise smoothing and prediction – Gauss Markov discrete time model – Estimation criteria – Minimum variance estimation – Least square estimation – Recursive estimation.

UNIT V KALMAN FILTER AND PROPERTIES 9

Filter problem and properties – Linear estimator property of Kalman Filter – Time invariance and asymptotic stability of filters – Time filtered estimates and signal to noise ratio improvement – Extended Kalman filter.

TOTAL: 45 PERIODS

REFERENCES:

1. KiRk D.E., 'Optimal Control Theory – An introduction', Prentice hall, N.J., 1970.
2. Sage, A.P., 'Optimum System Control', Prentice Hall N.H., 1968.
3. Anderson, BD.O. and Moore J.B., 'Optimal Filtering', Prentice hall Inc., N.J., 1979.
4. S.M. Bozic, "Digital and Kalman Filtering", Edward Arnould, London, 1979.
5. Astrom, K.J., "Introduction to Stochastic Control Theory", Academic Press, Inc, N.Y., 1970.

ET9278 APPLICATIONS OF MEMS TECHNOLOGY L T P C
3 0 0 3

UNIT I MEMS: MICRO-FABRICATION, MATERIALS AND ELECTRO-MECHANICAL CONCEPTS 9

Overview of micro fabrication – Silicon and other material based fabrication processes – Concepts: Conductivity of semiconductors-Crystal planes and orientation-stress and strain-flexural beam bending analysis-torsional deflections-Intrinsic stress- resonant frequency and quality factor.

UNIT II ELECTROSTATIC SENSORS AND ACTUATION 9

Principle, material, design and fabrication of parallel plate capacitors as electrostatic sensors and actuators-Applications

UNIT III THERMAL SENSING AND ACTUATION 9

Principle, material, design and fabrication of thermal couples, thermal bimorph sensors, thermal resistor sensors-Applications.

UNIT IV PIEZOELECTRIC SENSING AND ACTUATION 9

Piezoelectric effect-cantilever piezo electric actuator model-properties of piezoelectric materials-Applications.

UNIT V CASE STUDIES 9

Piezoresistive sensors, Magnetic actuation, Micro fluidics applications, Medical applications, Optical MEMS.

TOTAL: 45 PERIODS

REFERENCES

1. Chang Liu, “Foundations of MEMS”, Pearson International Edition, 2006.
2. Marc Madou , “Fundamentals of microfabrication”,CRC Press, 1997.
3. Boston , “Micromachined Transducers Sourcebook”,WCB McGraw Hill, 1998.
4. M.H.Bao “Micromechanical transducers :Pressure sensors, accelerometers and gyroscopes”, Elsevier, New york, 2000.