

**AFFILIATED INSTITUTIONS**  
**ANNA UNIVERSITY, CHENNAI**  
**REGULATIONS - 2009**

**M.E. POWER MANAGEMENT**  
**II TO IV SEMESTERS (FULL TIME) CURRICULUM AND SYLLABUS**

**SEMESTER II**

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
<b>THEORY</b>						
1	PS9321	<u>Power System Protection</u>	3	0	0	3
2	PS9322	<u>Power System Stability</u>	3	1	0	4
3	PS9323	<u>Flexible AC Transmission Systems</u>	3	0	0	3
4	PS9324	<u>Power System Restructuring and Deregulation</u>	3	0	0	3
5		Elective II	3	0	0	3
6		Elective III	3	0	0	3
<b>PRACTICAL</b>						
7	PS9325	<u>Power System Simulation Laboratory</u>	0	0	3	2
<b>TOTAL</b>			<b>18</b>	<b>1</b>	<b>3</b>	<b>21</b>

**SEMESTER III**

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
<b>THEORY</b>						
1		Elective IV	3	0	0	3
2		Elective V	3	0	0	3
3		Elective VI	3	0	0	3
<b>PRACTICAL</b>						
4	PS9331	Project work (Phase-I)	0	0	12	6
<b>TOTAL</b>			<b>9</b>	<b>0</b>	<b>12</b>	<b>15</b>

**SEMESTER IV**

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
<b>PRACTICAL</b>						
1	PS9341	Project work (Phase-II)	0	0	24	12
<b>TOTAL</b>			<b>0</b>	<b>0</b>	<b>24</b>	<b>12</b>

**TOTAL CREDITS TO BE EARNED FOR THE AWARD OF THE DEGREE: 22+21+15+12=70**

## ELECTIVES FOR M.E.POWER MANAGEMENT

### SEMESTER I

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
		<b>ELECTIVE I</b>				
1	PS9001	<u>Power System Dynamics</u>	3	0	0	3
2	PS9002	<u>Soft Computing Techniques</u>	3	0	0	3
3	PS9003	<u>Modeling and Analysis of Electrical Machines</u>	3	0	0	3

### SEMESTER II

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
		<b>ELECTIVE II</b>				
4	HV9324	<u>EHV Power Transmission</u>	3	0	0	3
5	CL9356	<u>Optimal Control and Filtering</u>	3	0	0	3
6	PE9261	<u>Power Quality</u>	3	0	0	3
		<b>ELECTIVE III</b>				
7	PS9262	<u>Power System Planning and Reliability</u>	3	0	0	3
8	ET9272	<u>Advanced Digital Signal Processing</u>	3	0	0	3
9	CL9313	<u>Control System Design</u>	3	1	0	4

### SEMESTER III

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
		<b>ELECTIVE IV</b>				
10	PE9223	<u>Special Electrical Machines</u>	3	0	0	3
11	PS9272	<u>Advanced Power System Dynamics</u>	3	0	0	3
12	CL9358	<u>System Identification and Adaptive Control</u>	3	0	0	3
		<b>ELECTIVE V</b>				
13	PS9274	<u>Industrial Power System Analysis and Design</u>	3	0	0	3
14	PS9275	<u>High Voltage Direct Current Transmission</u>	3	0	0	3
15	PS9276	<u>Wind Energy Conversion Systems</u>	3	0	0	3
		<b>ELECTIVE VI</b>				
16	PS9352	<u>AI Techniques to Power System</u>	3	0	0	3
17	PE9272	<u>Power Electronics for Renewable Energy Systems</u>	3	0	0	3
18	ET9278	<u>Applications of MEMS Technology</u>	3	0	0	3

**UNIT I EQUIPMENT PROTECTION 9**

Types of transformers – Phasor diagram for a three – Phase transformer-Equivalent circuit of transformer – Types of faults in transformers- Over – current protection - Percentage Differential Protection of Transformers - Inrush phenomenon-High resistance Ground Faults in Transformers - Inter-turn faults in transformers – Incipient faults in transformers - Phenomenon of over-fluxing in transformers – Transformer protection application chart .Electrical circuit of the generator –Various faults and abnormal operating conditions-rotor fault –Abnormal operating conditions; numerical examples for typical transformer and generator protection schemes.

**UNIT II OVER CURRENT PROTECTION 9**

Time – Current characteristics-Current setting – Time setting-Over current protective schemes - Reverse power or directional relay - Protection of parallel feeders - Protection of ring feeders - Earth fault and phase fault protection - Combined Earth fault and phase fault protection scheme - Phase fault protective scheme directional earth fault relay - Static over current relays; numerical example for a radial feeder.

**UNIT III DISTANCE AND CARRIER CURRENT PROTECTION FOR TRANSMISSION LINES 9**

Draw back of over – Current protection – Introduction to distance relay – Simple impedance relay – Reactance relay – mho relays comparison of distance relay – Distance protection of a three – Phase line-reasons for inaccuracy of distance relay reach - Three stepped distance protection - Trip contact configuration for the three - Stepped distance protection - Three-stepped protection of three-phase line against all ten shunt faults - Impedance seen from relay side - Three-stepped protection of double end fed lines-need for carrier – Aided protection – Various options for a carrier –Coupling and trapping the carrier into the desired line section - Unit type carrier aided directional comparison relaying – Carrier aided distance protection schemes for acceleration of zone II.; Numerical example for a typical distance protection scheme for a transmission line

**UNIT IV BUS BAR PROTECTION 9**

Introduction – Differential protection of busbars-external and internal fault – Actual behaviors of a protective CT - Circuit model of a saturated CT - External fault with one CT saturation; Need for high impedance – Minimum internal fault that can be detected by the high – Stability ratio of high impedance busbar differential scheme - Supervisory relay-protection of three – Phase busbars-Numerical examples on design of high impedance busbar differential scheme.

**UNIT V NUMERICAL PROTECTION 9**

Introduction – Block diagram of numerical relay - Sampling theorem- Correlation with a reference wave – Least error squared (LES) technique - Digital filtering-numerical over - Current protection – Numerical transformer differential protection-Numerical distance protection of transmission line.

**TOTAL : 45 PERIODS**

## REFERENCES:

1. Paithankar.Y.G and Bhide.S.R, "Fundamentals of Power System Protection", Prentice-Hall of India, 2003
2. Badri Ram and Vishwakarma.D.N, "Power System Protection and Switchgear", Tata McGraw- Hill Publishing Company, 2002.
3. Kundur.P, "Power System Stability and Control", Tata McGraw-Hill, 1993.

**PS9322**

**POWER SYSTEM STABILITY**

**L T P C**  
**3 1 0 4**

### **UNIT I INTRODUCTION 9**

Power System stability considerations – definitions- classification of stability – rotor angle and voltage stability- synchronous machine representation- classical model – load modeling- concepts- modeling of excitation systems – modeling of prime movers.

### **UNIT II TRANSIENT STABILITY ANALYSIS 9**

Transient stability-swing equation-equal area criterion-solution of swing equation-Numerical methods-Euler method-Runge-Kutte method-critical clearing time and angle-effect of excitation system and governors-Multimachine stability –extended equal area criterion- transient energy function approach.

### **UNIT III SMALL SIGNAL STABILITY 9**

Review of transmission aspects – Generation aspects : Review of synchronous machine theory - Voltage and frequency controllers – Limiting devices affecting voltage stability – V- Q characteristics of synchronous generators – Capability curves – Effect of machine limitation on deliverable power – Load aspects – Voltage dependence of loads – Load restoration dynamics – Induction motors – Load tap changers – Thermostatic load recovery – General aggregate load models.

### **UNIT IV VOLTAGE STABILITY 9**

Review of transmission aspects – Generation aspects : Review of synchronous machine theory - Voltage and frequency controllers – Limiting devices affecting voltage stability – V- Q characteristics of synchronous generators – Capability curves – Effect of machine limitation on deliverable power – Load aspects – Voltage dependence of loads – Load restoration dynamics – Induction motors – Load tap changers – Thermostatic load recovery – General aggregate load models.

### **UNIT V IMPROVING STABILITY 9**

Methods of improving stability – transient stability enhancement – high speed fault clearing – steam turbine fast valving -high speed excitation systems- Fundamentals and performance of Power System Stabilizer – Multi band PSS – Three dimensional PSS – Location & dispatch of reactive power by VAR sources.

**L: 45 T:15 TOTAL : 60 PERIODS**

## REFERENCES

1. Kundur, P., 'Power System Stability and Control', McGraw-Hill International Editions, 1994.
2. Anderson, P.M. and Fouad, A.A., 'Power System Control and Stability', Galgotia Publications, New Delhi, 1994.
3. Van Cutsem, T. and Vournas, C., 'Voltage Stability of Electric Power Systems', Kluwer Academic Publishers, 1998.
4. Taylor.C.W, Power system voltage stability, McGraw-Hill, 1994.
5. Kimbark.E.W, power system stability Vol. II John Wiley Sons, I. 1950

**PS9323**

**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**



## **UNIT V INDIAN POWER MARKET**

**9**

Current Scenario – Regions – Restructuring Choices – Statewise Operating Strategies – Salient features of Indian Electricity Act 2003 – Transmission System Operator – Regulatory and Policy development in Indian power Sector – Opportunities for IPP and Capacity Power Producer. Availability based tariff – Necessity – Working Mechanism – Beneficiaries – Day Scheduling Process – Deviation from Schedule – Unscheduled Interchange Rate – System Marginal Rate – Trading Surplus Generation – Applications.

**TOTAL: 45 PERIODS**

### **REFERENCES:**

1. Kankar Bhattacharya, Math H.J. Bollen and Jaap E. Daalder, "Operation of Restructured Power Systems", Kluwer Academic Publishers, 2001
2. Loi Lei Lai, "Power system Restructuring and Regulation", John Wiley sons, 2001.
3. Shahidehpour.M and Alomoush.M, "Restructuring Electrical Power Systems", Marcel Decker Inc., 2001.
4. Steven Stoff, " Power System Economics", Wiley – IEEE Press, 2002
5. Daniel S. Kirschen and Goran Strbac, " Fundamentals of Power System Economics", John Wiley & Sons Ltd., 2004.
6. Scholarly Transaction Papers and Utility web sites

Web Sites:

1. [www.pjm.com](http://www.pjm.com)
2. [www.caiso.com](http://www.caiso.com)
3. [www.midwestiso.com](http://www.midwestiso.com)

**PS9325**

**POWER SYSTEM SIMULATION LABORATORY**

**L T P C  
0 0 3 2**

1. Formation of bus admittance and bus impedance matrix.
2. Power flow analysis by Gauss – Seidel method.
3. Power flow analysis by Newton - Raphson method.
4. Short circuit studies.
5. Symmetrical components.
6. Stability studies.
7. Contingency analysis: Generator shift factors and line outage distribution factor.





### **UNIT III SMALL SIGNAL STABILITY ANALYSIS WITHOUT CONTROLLERS**

**9**

Classification of Stability, Basic Concepts and Definitions: Rotor angle stability, The Stability Phenomena. Fundamental Concepts of Stability of Dynamic Systems: Statespace representation, stability of dynamic system, Linearisation, Eigen properties of the state matrix: Eigen values and eigenvectors, modal matrices, eigen value and stability, mode shape and participation factor. Single-Machine Infinite Bus (SMIB) Configuration: Classical Machine Model stability analysis with numerical example, Effects of Field Circuit Dynamics: synchronous machine, network and linearised system equations, block diagram representation with K-constants; expression for K-constants (no derivation), effect of field flux variation on system stability: analysis with numerical example.

### **UNIT IV SMALL SIGNAL STABILITY ANALYSIS WITHOUT CONTROLLERS**

**9**

Effects Of Excitation System: Equations with definitions of appropriate K-constants and simple thyristor excitation system and AVR, block diagram with the excitation system, analysis of effect of AVR on synchronizing and damping components using a numerical example, Power System Stabiliser: Block diagram with AVR and PSS, Illustration of principle of PSS application with numerical example, Block diagram of PSS with description, system state matrix including PSS, analysis of stability with numerical a example. Multi-Machine Configuration: Equations in a common reference frame, equations in individual machine rotor coordinates, illustration of formation of system state matrix for a two-machine system with classical models for synchronous machines, illustration of stability analysis using a numerical example. Principle behind small-signal stability improvement methods: delta-omega and delta P-omega stabilizers.

### **UNIT V ENHANCEMENT OF SMALL SIGNAL STABILITY**

**9**

Power System Stabilizer – Stabilizer based on shaft speed signal (delta omega) – Delta –P-Omega stabilizer-Frequency-based stabilizers – Digital Stabilizer – Excitation control design – Exciter gain – Phase lead compensation – Stabilizing signal washout stabilizer gain – Stabilizer limits

**TOTAL : 45 PERIODS**

### **REFERENCES**

1. Kundur.P, "Power System Stability and Control", McGraw-Hill, 1993.
2. IEEE Committee Report, "Dynamic Models for Steam and Hydro Turbines in Power System Studies", IEEE Trans., Vol.PAS-92, pp 1904-1915,November December, 1973. on Turbine-Governor Model.
3. Anderson.P.M and Fouad.A.A, "Power System Control and Stability", Iowa State University Press, Ames, Iowa, 1978

**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.

**UNIT I PRINCIPLES OF ELECTROMAGNETIC ENERGY CONVERSION 9**

Introduction to self commutated switches : MOSFET and IGBT - Principle of operation of half and full bridge inverters – Performance parameters – Voltage control of single phase inverters using various PWM techniques – various harmonic elimination techniques – forced commutated Thyristor inverters.

**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 torque 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 torque equations – transformation for rotor circuits – voltage and torque 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**

**REFERENCES**

1. Paul C.Krause, OlegWasyzczyk, Scott S, Sudhoff, “Analysis of Electric Machinery and Drive Systems”, IEEE Press, Second Edition.
2. Krishnan.R, “Electric Motor Drives, Modeling, Analysis and Control” , Prentice Hall of India, 2002
3. Samuel Seely, “ Electromechanical Energy Conversion”, Tata McGraw Hill Publishing Company,
4. Fitzgerald.A.E, Charles Kingsley, Jr, and Stephan D, Umanx, “ Electric Machinery”, Tata McGraw Hill, 5th Edition, 1992

**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 GRADIENT 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](http://www.microtran.com)).

<b>UNIT I</b>	<b>INTRODUCTION</b>	<b>9</b>
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		
<b>UNIT II</b>	<b>L Q CONTROL PROBLEMS AND DYNAMIC PROGRAMMING</b>	<b>9</b>
Linear optimal regulator problem – Matrix Riccati 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.		
<b>UNIT III</b>	<b>NUMERICAL TECHNIQUES FOR OPTIMAL CONTROL</b>	<b>9</b>
Numerical solution of 2-point boundary value problem by steepest descent and Fletcher Powell method solution of Riccati equation by negative exponential and interactive Methods		
<b>UNIT IV</b>	<b>FILTERING AND ESTIMATION</b>	<b>9</b>
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		
<b>UNIT V</b>	<b>KALMAN FILTER AND PROPERTIES</b>	<b>9</b>
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, B.D.O. and Moore J.B., ‘Optimal Filtering’, Prentice hall Inc., N.J., 1979.
4. Bozic.S.M, “Digital and Kalman Filtering”, Edward Arnould, London, 1979.
5. Astrom, K.J., “Introduction to Stochastic Control Theory”, Academic Press, Inc, N.Y., 1970.

- 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: Detroit 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**

**REFERENCES:**

1. Arindam Ghosh "Power Quality Enhancement Using Custom Power Devices", Kluwer Academic Publishers, 2002.
2. Heydt.G.T, "Electric Power Quality", Stars in a Circle Publications, 1994(2nd edition)
3. Dugan.R.C, "Electrical Power System Quality",TMH,2008.
4. Arrillaga.A.J and Neville R.Watson, Power System Harmonics, John Wiley Second Edition,2003.
5. Derek A. Paice, "Power electronic converter harmonics",John Wiley & sons, 1999.

**UNIT I LOAD FORECASTING 9**

Objectives of forecasting - Load growth patterns and their importance in planning – Load forecasting Based on discounted multiple regression technique-Weather sensitive load forecasting-Determination of annual forecasting-Use of AI in load forecasting.

**UNIT II GENERATION SYSTEM RELIABILITY ANALYSIS 9**

Probabilistic generation and load models- Determination of LOLP and expected value of demand not served –Determination of reliability of iso and interconnected generation systems.

**UNIT III TRANSMISSION SYSTEM RELIABILITY ANALYSIS 9**

Deterministic contingency analysis-probabilistic load flow-Fuzzy load flow probabilistic transmission system reliability analysis-Determination of reliability indices like LOLP and expected value of demand not served.

**UNIT IV EXPANSION PLANNING 9**

Basic concepts on expansion planning-procedure followed for integrate transmission system planning, current practice in India-Capacitor placer problem in transmission system and radial distributions system

**UNIT V DISTRIBUTION SYSTEM PLANNING OVERVIEW 9**

Introduction, sub transmission lines and distribution substations-Design primary and secondary systems-distribution system protection and coordination of protective devices.

**TOTAL : 45 PERIODS****REFERENCES:**

- 1.. Proceeding of work shop on energy systems planning & manufacturing CI.
2. R.L .Sullivan, "Power System Planning".McGraw Hill, New York, 1977
3. Roy Billinton and Ronald.N.Allan, "Power System Reliability.", Springer, 1996
4. Turan Gonen, Electric power distribution system Engineering 'McGraw Hill, 1986.

**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 ESTIMATION 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 system 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, Stephen 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. Proakis, Dimitris G. Manolakis, "Digital Signal Processing", Pearson Education 2002.
5. Salivahanan.S, Vallavaraj.A and Gnanapriya.C, "Digital Signal Processing", TMH,2000.
6. Avatar Sing, Srinivasan.S, "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.

**CL9313**

**CONTROL SYSTEM DESIGN**

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**UNIT I CONVENTIONAL DESIGN METHODS 9**

Design specifications- PID controllers and compensators- Root locus based design- Bode based design- Design examples

**UNIT II DESIGN IN DISCRETE DOMAIN 9**

Sample and Hold-Digital equivalents-Impulse and step invariant transformations- Methods of discretisation-Effect of sampling- Direct discrete design – discrete root locus - Design examples.



**UNIT III OPTIMAL CONTROL 9**  
 Formation of optimal control problems-results of Calculus of variations- Hamiltonian formulation-solution of optimal control problems- Evaluation of Riccati's equation State and output Regulator problems-Design examples

**UNIT IV DISCRETE STATE VARIABLE DESIGN 9**  
 Discrete pole placement- state and output feedback-estimated state feedback-discrete optimal control- dynamic programming-Design examples

**UNIT V STATE ESTIMATION 9**  
 State Estimation Problem -State estimation- Luenberger's observer-noise characteristics- Kalman-Bucy filter-Separation Theorem-Controller Design-Wiener filter-Design examples

**TOTAL : 45 PERIODS**

**REFERENCES:**

1. Gopal.M "Modern control system Theory" New Age International, 2005.
2. Benjamin C. Kuo "Digital control systems", Oxford University Press, 2004.
3. Franklin.G.F, Powell.J.D and Naeini.A.E "Feedback Control of Dynamic Systems", PHI (Pearson), 2002.
4. Graham C. Goodwin, Stefan F. Graebe and Mario E. Salgado "Control system Design", PHI (Pearson), 2003.
5. Franklin.G.F, Powell.J.D and Workman.M, "Digital Control of Dynamic Systems", PHI (Pearson), 2002.
6. Anderson.B.D.O and Moore.J.B., 'Optimal Filtering', Prentice hall Inc., N.J., 1979.
7. Loan D. Landau, Gianluca Zito," Digital Control Systems, Design, Identification and Implementation", Springer, 2006.

**PE9223 SPECIAL ELECTRICAL MACHINES L T P C  
 3 0 0 3**

**UNIT I SYNCHRONOUS RELUCTANCE MOTORS 9**  
 Constructional features: axial and radial air gap Motors. Operating principle, reluctance torque – phasor diagram, motor characteristics – Linear induction machines.

**UNIT II STEPPING MOTORS 9**  
 Constructional features, principle of operation, modes of excitation torque production in Variable Reluctance (VR) stepping motor, Dynamic characteristics, Drive systems and circuit for open loop control, Closed loop control of stepping motor

**UNIT III SWITCHED RELUCTANCE MOTORS 9**  
 Constructional features-principle of operation-Torque equation-Power Controllers Characteristics and control Microprocessor based controller.

**UNIT IV PERMANENT MAGNET SYNCHRONOUS MOTORS 9**  
Principle of operation, EMF, power input and torque expressions, Phasor diagram, Power controllers, 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-Microprocessor 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. Kenjo, T and Naganori, S "Permanent Magnet and brushless DC motors ", Clarendon Press, Oxford, 1989
4. Kenjo, T. "Power Electronics for the microprocessor Age", , Oxford university Press, 1996
5. Bose.B.K, "Modern Power Electronics & AC drives", Newyork, IEEE Press
6. Krishnan.R, "Electric Motor Drives- Modelling, Analysis and Control", Prentice-Hall Of India Pvt Ltd, New Delhi 2003

**PS9272 ADVANCED POWER SYSTEM DYNAMICS**

**L T P C  
3 0 0 3**

**UNIT I TRANSIENT STABILITY ANALYSIS 9**  
Review of numerical integration methods: Euler and Fourth Order Runge-Kutta methods, Numerical stability and implicit methods, Simulation of Power System Dynamic response: Structure of Power system Model, Synchronous machine representation: equations of motion, rotor circuit equations, stator voltage equations, Thevenin's and Norton's equivalent circuits, Excitation system representation, Transmission network and load representation, Overall system equations and their solution: Partitioned – Explicit and Simultaneous-implicit approaches, treatment of discontinuities, Simplified Transient Stability Simulation using implicit integration method.

**UNIT II SUB-SYNCHRONOUS OSCILLATIONS 9**  
Introduction – Turbine Generator Torsional Characteristics: Shaft system model – Examples of torsional characteristics – Torsional Interaction with Power System Controls: Interaction with generator excitation controls – Interaction with speed governors – Interaction with nearby DC converters.

**UNIT III SUB-SYNCHRONOUS RESONANCE 9**

Subsynchronous Resonance (SSR): Characteristics of series –Compensated transmission systems – Self-excitation due to induction generator effect – Torsional interaction resulting in SSR – Analytical Methods – Numerical examples illustrating instability of subsynchronous oscillations – Impact of Network-Switching Disturbances: Steady-state switching – Successive network-Switching disturbances – Torsional Interaction Between Closely Coupled Units; time-domain simulation of subsynchronous resonance – EMTF with detailed synchronous machine model.

**UNIT IV TRANSMISSION, GENERATION AND LOAD ASPECTS OF VOLTAGE STABILITY ANALYSIS 9**

Review of transmission aspects – Generation Aspects: Review of synchronous machine theory – Voltage and frequency controllers – Limiting devices affecting voltage stability – Voltage-reactive power characteristics of synchronous generators – Capability curves – Effect of machine limitation on deliverable power – Load Aspects – Voltage dependence of loads – Load restoration dynamics – Induction motors – Load tap changers – Thermostatic load recovery – General aggregate load models.

**UNIT V ENHANCEMENT OF TRANSIENT STABILITY AND COUNTER MEASURES FOR SUB-SYNCHRONOUS RESONANCE 9**

Principle behind transient stability enhancement methods: high-speed fault clearing, reduction of transmission system reactance, regulated shunt compensation, dynamic braking, reactor switching, independent pole-operation of circuit-breakers, single-pole switching, fast-valving, high-speed excitation systems; NGH damper scheme

**TOTAL: 45 PERIODS**

**REFERENCES:**

1. Kundur.P, Power System Stability and Control, McGraw-Hill, 1993.
2. Dommel.H.W and Sato.N, "Fast Transient Stability Solutions," IEEE Trans., Vol. PAS-91, pp, 1643-1650, July/August 1972
3. AU Power Lab Laboratory Manuals, Anna University, pp : 7-1 to 7-12, May 2004
4. Dommel.H.W, EMTF THEORY BOOK, Microtran Power System Analysis Corporation, Second Edition, 1996
5. Cutsem.T.V and Vournas.C, "Voltage Stability of Electric Power Systems", Kluwer publishers,1998

**CL9358 SYSTEM IDENTIFICATION AND ADAPTIVE CONTROL L T P C 3 0 0 3**

**UNIT I MODELS FOR IDENTIFICATION 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 NON-PARAMETRIC IDENTIFICATION 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 CONTROL 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

**PS9274 INDUSTRIAL POWER SYSTEM ANALYSIS DESIGN L T P C 3 0 0 3**

**UNIT I MOTOR STARTING STUDIES 9**

Introduction-Evaluation Criteria-Starting Methods-System Data-Voltage Drop Calculations-Calculation of Acceleration time-Motor Starting with Limited-Capacity Generators-Computer-Aided Analysis-Conclusions.

**UNIT II POWER FACTOR CORRECTION STUDIES 9**

Introduction-System Description and Modeling-Acceptance Criteria-Frequency Scan Analysis-Voltage Magnification Analysis-Sustained Overvoltages-Switching SurgeAnalysis-Back-to-Back Switching-Summary and Conclusions.

**UNIT III HARMONIC ANALYSIS 9**

Harmonic Sources-System Response to Harmonics-System Model for Computer-Aided Analysis-Acceptance Criteria-Harmonic Filters-Harmonic Evaluation-Case Study- Summary and Conclusions.

**UNIT IV FLICKER ANALYSIS 9**  
Sources of Flicker-Flicker Analysis-Flicker Criteria-Data for Flicker analysis- Case Study- Arc Furnace Load-Minimizing the Flicker Effects-Summary.

**UNIT V GROUND GRID ANALYSIS 9**  
Introduction-Acceptance Criteria-Ground Grid Calculations-Computer-Aided Analysis - Improving the Performance of the Grounding Grids-Conclusions.

**TOTAL: 45 PERIODS**

**REFERENCE:**

1. Ramasamy Natarajan, "Computer-Aided Power System Analysis", Marcel Dekker Inc 2002

**PS9275 HIGH VOLTAGE DIRECT CURRENT TRANSMISSION L T P C  
3 0 0 3**

**UNIT I DC POWER TRANSMISSION TECHNOLOGY 9**  
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 9**  
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 interaction between DC and AC systems

**TOTAL: 45 PERIODS**

## REFERENCES:

1. Padiyar.K.R, , "HVDC Power Transmission Systems", New Age International (P) Ltd., New Delhi, 2002
2. Arrillaga.J, , "High Voltage Direct Current Transmission", Peter Pregrinus, London,1983.
3. Kundur.P, "Power System Stability and Control", McGraw-Hill, 1993
4. Erich Uhlmann, " Power Transmission by Direct Current", BS Publications, 2004.
5. Sood.V.K,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 BASICS OF WIND ENERGY CONVERSION 9

History of wind energy, Current status and future prospects, Wind resource assessment, Wind Speed Prediction, Wind Power estimation techniques, Site Selection. WECS-System Components, Turbine Rating; Speed and Power Relations, Power Extracted from the Wind, Rotor swept area, Air Density, Global Wind Patterns; Maximum Energy Capture, Maximum Power Operation-Constant-TSR Scheme and Peak-Power-Tracking Scheme, System.

### UNIT II WIND TURBINES 9

Simple momentum theory-Power coefficient-Sabinin's theory-Aerodynamics of Wind turbine; Design Trade-offs-Turbine Towers and Spacing, Number of Blades; Power Output from an Ideal and practical Turbines. Types of Wind turbine- Vertical Axis Type, Horizontal Axis-Power developed -Thrust-Efficiency-Rotor selection-Rotor design considerations-Tip speed ratio-Regulation-yaw control-Pitch angle control-stall control, Upwind, Downwind.

### 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 INTEGRATION AND POWER QUALITY 9

Stand alone and Grid Connected WECS system- Basics of Grid Connection; Characteristics of Wind Generator; State-of-the-art of power electronics in Wind Energy - Soft-starter, Capacitor bank, Rectifiers and inverters, Frequency converters. Power Converters for WECS; Power Quality Standards in Wind Farms-Reactive power, flicker coefficient, Maximum number of wind turbine switching operations, flicker step factor, Voltage change factor, Harmonic currents.

**TOTAL: 45 PERIODS**

**REFERENCES:**

1. L.L.Freris "Wind Energy conversion Systems", Prentice Hall, 1990.
2. Ion Boldea, "Variable speed generators", Taylor and Francis group, 2006.
3. Sathyajith Mathew, "Wind Energy-Fundamentals, Resource Analysis and Economics", Springer, 2006.
4. Frede Blaabjerg and Zhe Chen, "Power Electronics for Modern Wind Turbines" Morgan and Claypool Publishers, 2006.
5. Muyeen.S.M, Junji Tamura and Toshiaki Murata, "Stability Augmentation of a Grid- connected Wind Farm" Springer-Verlag London Limited, 2009.
6. Erich Hau, "Wind Turbines-Fundamentals, Technologies, Application, Economics" Springer, 2006

**PS9352**

**AI TECHNIQUES TO POWER SYSTEM**

**L T P C**  
**3 0 0 3**

**UNIT I INTRODUCTION TO NEURAL NETWORKS 9**

Basics of ANN - perceptron - delta learning rule - back propagation algorithm - multilayer feed forward network - memory models - bi-directional associative memory - Hopfield network.

**UNIT II APPLICATIONS TO POWER SYSTEM PROBLEMS 9**

Application of neural networks to load forecasting - contingency analysis - VAR control - economic load dispatch.

**UNIT III INTRODUCTION TO FUZZY LOGIC 9**

Crispness - vagueness - fuzziness - uncertainty - fuzzy set theory fuzzy sets - fuzzy set operations - fuzzy measures - fuzzy relations - fuzzy function - structure of fuzzy logic controller – fuzzification models - data base - rule base - inference engine defuzzification module.

**UNIT IV APPLICATIONS TO POWER SYSTEMS 9**

Decision making in power system control through fuzzy set theory - use of fuzzy set models of LP in power systems scheduling problems - fuzzy logic based power system stabilizer.

**UNIT V GENETIC ALGORITHM AND ITS APPLICATIONS TO POWER SYSTEMS 9**

Introduction - simple genetic algorithm - reproduction - crossover - mutation – advanced operators in genetic search - applications to voltage control and stability studies.

**TOTAL: 45 PERIODS**

**REFERENCES:**

1. James A. Freeman and Skapura.B.M, 'Neural Networks - Algorithms Applications and Programming Techniques', Addison Wesley, 1990.
2. George Klir and Tina Folger.A, 'Fuzzy sets, Uncertainty and Information', Prentice Hall of India, 1993.
3. Zimmerman.H.J, 'Fuzzy Set Theory and its Applications', Kluwer Academic Publishers 1994.
4. IEEE tutorial on 'Application of Neural Network to Power Systems', 1996.

5. Loi Lei Lai, 'Intelligent System Applications in Power Engineering', John Wiley & Sons Ltd., 1998.

<b>PE9272</b>	<b>POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS</b>	<b>L T P C 3 0 0 3</b>
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| <b>UNIT I</b>  | <b>INTRODUCTION</b>  | <b>9</b> |
| Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission) - Qualitative study of different renewable energy resources: Solar, wind, ocean, Biomass, Fuel cell, Hydrogen energy systems and hybrid renewable energy systems.   |  |          |
| <b>UNIT II</b>   | <b>ELECTRICAL MACHINES FOR RENEWABLE ENERGY CONVERSION</b> | <b>9</b> |
| Review of reference theory fundamentals-principle of operation and analysis: IG, PMSG, SCIG and DFIG.  |  |          |
| <b>UNIT III</b>  | <b>POWER CONVERTERS</b>                                    | <b>9</b> |
| Solar: Block diagram of solar photo voltaic system -Principle of operation: line commutated converters (inversion-mode) - Boost and buck-boost converters-selection Of inverter, battery sizing, array sizing Wind: three phase AC voltage controllers- AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid Interactive Inverters-matrix converters. |  |          |
| <b>UNIT IV</b>   | <b>ANALYSIS OF WIND AND PV SYSTEMS</b>                     | <b>9</b> |
| Stand alone operation of fixed and variable speed wind energy conversion systems and solar system-Grid connection Issues -Grid integrated PMSG and SCIG Based WECS Grid Integrated solar system.   |  |          |
| <b>UNIT V</b>  | <b>HYBRID RENEWABLE ENERGY SYSTEMS</b>                     | <b>9</b> |
| Need for Hybrid Systems- Range and type of Hybrid systems- Case studies of Wind-PVMaximum Power Point Tracking (MPPT).   |  |          |

**TOTAL: 45 PERIODS**

**REFERENCES:**

1. Rashid .M. H "power electronics Hand book", Academic press, 2001.
2. Rai. G.D, "Non conventional energy sources", Khanna publishes, 1993.
3. Rai. G.D," Solar energy utilization", Khanna publishes, 1993.
4. Gray, L. Johnson, "Wind energy system", prentice hall linc, 1995.
5. Non-conventional Energy sources B.H.Khan Tata McGraw-hill Publishing Company, New Delhi.



<b>UNIT I</b>	<b>MEMS: MICRO-FABRICATION, MATERIALS AND ELECTROMECHANICAL CONCEPTS</b>	<b>9</b>
	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.	
<b>UNIT II</b>	<b>ELECTROSTATIC SENSORS AND ACTUATION</b>	<b>9</b>
	Principle, material, design and fabrication of parallel plate capacitors as electrostatic sensors and actuators-Applications.	
<b>UNIT III</b>	<b>THERMAL SENSING AND ACTUATION</b>	<b>9</b>
	Principle, material, design and fabrication of thermal couples, thermal bimorph sensors, thermal resistor sensors-Applications.	
<b>UNIT IV</b>	<b>PIEZO ELECTRIC SENSING AND ACTUATION</b>	<b>9</b>
	Piezoelectric effect-cantilever piezo electric actuator model-properties of piezoelectric materials-Applications.	
<b>UNIT V</b>	<b>CASE STUDIES</b>	<b>9</b>
	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 micro fabrication", CRC Press, 1997.
3. Boston , "Micro machined Transducers Source book", WCB McGraw Hill, 1998.
4. Bao.M.H "Micromechanical transducers :Pressure sensors, accelerometers and gyroscopes", Elsevier, New York, 2000