BRANCH-ELECTRICAL ENGINEERING

2nd Semester

Specialization: Power System Engineering/ Power Systems/ Electrical Power Systems

Second Semester							
Theory					Practical		
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Electrical Power System Transient	4-0	4	100	50	-	-	-
Specialization Core-2 Power System Dynamics	4-0	4	100	50	-	-	-
Elective I(Specialization related) 1.HVDC Transmission & FACTS 2.EHVAC Transmission 3.Computer Aided Power System Protection 4.Power System Reliability	4-0	4	100	50	-	-	-
Elective II (Departmental related) 1.Advance Control System 2. Energy Generation From Waste 3.Power Quality Improvement Techniques 4.Power System Control & Instrumentation	4-0	4	100	50	-	-	-
Elective III(from any department) 1. Electric Drives In Hybrid Vehicle 2.Green Energy Resources & Technology 3. Quantitative methods For Energy Management & planning 4.Advanced Numerical Methods	4-0	4	100	50	-	-	-
Lab-2 (Specialization lab to be decided by the department)					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

BRANCH-ELECTRICAL ENGINEERING

2nd Semester

Specialization: Power Electronics & Drives/ Power Electronics/ Power Electronics & Electrical Drives

Second Semester							
Theory					Practical		
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Advanced Power Converter	4-0	4	100	50	-	-	-
Specialization Core-2 Advanced Electric Drives	4-0	4	100	50	-	-	-
Elective I(Specialization related) 1.HVDC Transmission & FACTS 2.Electrical Machine Analysis & Control 3.Power System Transient 4.Control Techniques In Power Electronics	4-0	4	100	50	-	-	-
Elective II (Departmental related) 1.Advance Control System 2. Energy Generation From Waste 3.Power Quality Improvement Techniques 4.Power System Control & Instrumentation	4-0	4	100	50	-	-	-
Elective III(from any department) 1. Electric Drives In Hybrid Vehicle 2.Green Energy Resources & Technology 3. Quantitative methods For Energy Management & planning 4.Advanced Digital Signal Processing	4-0	4	100	50	-	-	-
Lab-2 (Specialization lab to be decided by the department)					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

BRANCH-ELECTRICAL ENGINEERING

2nd Semester

Specialization: Power Electronics & Power System

Second Semester							
Theory					**Practical**		
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Advanced Power Converter	4-0	4	100	50	-	-	-
Specialization Core-2 Power System Dynamics	4-0	4	100	50	-	-	-
Elective I(Specialization related) 1.HVDC Transmission & FACTS 2.Electrical Machine Analysis & Control 3.Power System Transient 4.Control Techniques In Power Electronics	4-0	4	100	50	-	-	-
Elective II (Departmental related) 1.Advance Control System 2. Energy Generation From Waste 3.Power Quality Improvement Techniques 4.Power System Control & Instrumentation	4-0	4	100	50	-	-	-
Elective III(from any department) 1. Electric Drives In Hybrid Vehicle 2.Green Energy Resources & Technology 3. Quantitative methods For Energy Management & planning 4.Advance Microprocessor & Microcontroller	4-0	4	100	50	-	-	-
Lab-2 (Specialization lab to be decided by the department)					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

BRANCH-ELECTRICAL ENGINEERING

2nd Semester

Specialization: Power Engineering and Energy System/ Power And Energy Engineering

Second Semester							
Theory					**Practical**		
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Foundation For Energy Systems Technology	4-0	4	100	50	-	-	-
Specialization Core-2 Power System Dynamics	4-0	4	100	50	-	-	-
Elective I(Specialization related) 1.HVDC Transmission & FACTS 2.EHVAC Transmission 3.Operation & Control Of Electrical Energy Systems 4.Power System Reliability	4-0	4	100	50	-	-	-
Elective II (Departmental related) 1.Advance Control System 2. Energy Generation From Waste 3.Power Quality Improvement Techniques 4.Protection & Digital Relaying	4-0	4	100	50	-	-	-
Elective III(from any department) 1. Electric Drives In Hybrid Vehicle 2.Green Energy Resources & Technology 3. Quantitative methods For Energy Management & planning 4.System Identification & Adaptive Control	4-0	4	100	50	-	-	-
Lab-2 (Specialization lab to be decided by the department)					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

BRANCH-ELECTRICAL ENGINEERING

2nd Semester

Specialization: Energy System Engineering

Second Semester							
Theory					**Practical**		
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Solar Energy Engineering	4-0	4	100	50	-	-	-
Specialization Core-2 Wind and Small Hydro System	4-0	4	100	50	-	-	-
Elective I(Specialization related) 1.HVDC Transmission & FACTS 2.Operation & control of Electrical Energy System 3.Energy System Modeling & Analysis 4.Energy Resources, Economics & Environment	4-0	4	100	50	-	-	-
Elective II(Departmental related) 1.Power System Planning & Operation 2.Energy Generation From Waste 3.Computer Aided Power System Analysis 4.Power System Control & Instrumentation	4-0	4	100	50	-	-	-
Elective III(from any department) 1.Electric Drives In Hybrid Vehicles 2. Green Energy Resources & Technology 3.Quantitative methods For Energy Management & Planning 4. Energy Efficiency in Electrical Utility	4-0	4	100	50	-	-	-
Lab-2 (Specialization lab to be decided by the department)					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

DETAILED SYLLABUS OF SECOND SEMISTER M.TECH 2016-17 ADDMISSION BATCH

BRANCH-Electrical Engineering

Specialization:Power System Engineering/ Power Systems/ Electrical Power Systems

Second Semester							
Theory					Practical		
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Electrical Power System Transient	4-0	4	100	50	-	-	-
Specialization Core-2 Power System Dynamics	4-0	4	100	50	-	-	-
Elective I(Specialization related) 1.HVDC Transmission & FACTS 2.EHVAC Transmission 3.Computer Aided Power System Protection 4.Power System Reliability	4-0	4	100	50	-	-	-
Elective II (Departmental related) 1.Advance Control System 2. Energy Generation From Waste 3.Power Quality Improvement Techniques 4.Power System Control & Instrumentation	4-0	4	100	50	-	-	-
Elective III(from any department) 1. Electric Drives In Hybrid Vehicle 2.Green Energy Resources & Technology 3. Quantitative methods For Energy Management & planning 4.Advanced Numerical Methods	4-0	4	100	50	-	-	-
Lab-2 (Specialization lab to be decided by the department)					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

ELECTRICAL POWER SYSTEMS TRANSIENT

Module-I (11 Hours)

INTRODUCTION TO FAST TRANSIENTS:

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

Module-I (10 Hours)

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

THEORY OF GROUNDS WIRES : Direct stoke to a tower, effect of reflection up and down the tower , the counterpoise.

Module-III (10Hours)

SWITCHING SURGES :

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

HIGH FREQUENCY OSCILLATIONS AND TERMINAL TRANSIENTS OF TRANSFORMER

Module-IV (12 Hours)

INSULATION COORDINATION:

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

TEXT BOOKS

1.Allan Greenwood , Electrical Transients in power Systems , Wiley Iterscience, 1991
2.Lou Van Der Sluis, Transients in power Systems , John Wiley & Sons Ltd, 2001
3.RRudenterg, Transient Performance of Electric power systems, Phenomenon in Lumped Networks, MGH, 1950
4.RRudenterg, Electric Stroke waves in power systems, Harvard University press, Cambridge, Massachusetts, 1968
5.Transmission Line Reference Book, EPRI, USA, 1982 11

POWER SYSTEM DYNAMICS

Module-I (15 Hours)

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

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

Module-II (15 Hours)

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

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

Module-III (15 Hours)

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

Module IV(15 Hours)

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

Voltage stability, System oscillations

Text Books:

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

2.P. Sauer and M. Pai, *Power system dynamics and stability*, Prentice Hall, 1998. 12

HVDC TRANSMISSION& FACTS

Module-I(10hours)

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

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

Module-II :(11hours)

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

Module-III:(15hours)

FACTS Concept and General System:

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

Module-IV:(15hours)

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

Text/References:

1.Padiyar K.R., “HVDC Power Transmission System”, Wiely Eastern PVT Limited

2.Kimbark, “Direct Current transmission”, Vol.1, John Wielly, New York, 1971

3.Understanding FACTS: Cocepts and Technology of Flexible AC Transmission Systems. By N. G. Hingorani and L. Gyugi, Standard Publisher Distributors, IEEE Press, Delhi

4.Flexible AC Transmission Systems. By J. Arillage 13

EHVAC TRANSMISSIONS

Module- I (10 hrs)

Introduction to EHV Transmission Comparison of AC and DC Transmission Systems. Parameters of EHV Lines:- Resistance of conductors, bundle conductors, Inductance of EHV Line configurations line capacitance, Sequence Inductance and capacitance, Line parameters for modes of propagation, resistance and Inductance of Ground returns.

Module- II (10 hrs)

Voltage Gradient of conductors:- Field of sphere gap, field of line charges and their properties. Charge – potential relations for multi-conductor lines surface voltage gradient and conductors without and with ground wires consideration, gradient factors, Distribution of voltage gradient on sub-conductors of bundle.

Module- III (10 hrs)

Corona effects- I : Power loss and Audible Noise Corona loss, Charge- Voltage diagram. Attenuation of traveling waves Audible.

Noise: Generation, Characteristics and its limitation, Measurement, meters, 1-phase and 3-phase AN levels, Day-Night equivalent Noise level.

Power frequency voltage control and over-voltage:- Generalised constants, Cascade connection of components-shunt and series compensation. Sub-synchronous Resonance in series- capacitor compensated lines, Static Reactive compensating systems.

Module – IV (10 hrs)

Over voltage in EHV systems caused by switching operations:-

Origin of over voltage and their types, short circuit current and circuit breaker. Recovery voltage and the circuit breaker, Over voltage caused by interruption of inductive current, Interruption of capacitive currents, Ferro resonance over voltage, calculation of switching surges single phase equivalents, distributed parameter line energized by source, generalized equations for single phase representation, Generalised equation of three phase systems, inverse Fourier transform for the general case, Reduction of switching surges on EHV systems, Experimental and calculated results of switching surge studies.

Text Books:-

1. *Begamudre R.D., "Extra High Voltage A.C. Transmission" McGraw Hill 1968.*

COMPUTER AIDED POWER SYSTEM PROTECTION

Module-I (12 Hours)

Introduction To Computer Relaying: Development of computer relaying, Historical background, Expected benefits of computer relaying, Computer relay architecture, Analog to digital converter, Anti-aliasing filter, Substation computer hierarchy.

Relaying Practices: Introduction to protection systems, Functions of a protection system, Protection of transmission lines, Transformer, reactor & generator protection, Bus protection, Performance of current & voltage transformers.

Module-II (11 Hours)

Mathematical Basis For Protective Relaying Algorithms: Introduction, Fourier series, Other orthogonal expansion, Fourier transform, Use of fourier transform, Discrete fourier transform, Introduction to probability & random processes, Random processes, Kalman filtering.

Transmission Line Relaying: Introduction, Sources of error, relaying as parameter estimation, Beyond parameter estimation, Symmetrical component distance relay, protection of series compensated lines.

Module-III (10 Hours)

Protection Of Transformers, Machines & Buses: Introduction, Power transformer algorithms, Generator protection,, Motor protection, Digital bus protection.

Hardware Organisation In Integarted Systems: The nature of hardware issues, Computers for relaying, The substation environment, Industry environmental standards, Countermeasures against EMI, Supplementary equipment, Redundancy & backup, Servicing, training & maintenance.

Module-IV (11 Hours)

System Relaying & Control: Introduction, Measurement of frequency & phase, Sampling clock synchronization, Application of phasor measurements to state estimation, Phasor measurement in dynamic state estimation, Monitoring.

Developments In New Relaying Principles: Introduction, Traveling waves on single-phase lines, Traveling waves on three-phase lines, Traveling waves due to faults, Directional wave relays, Traveling wave distance relay, Differential relaying with phasors, Traveling ` wave differential relays, Adaptive relaying,

Text Book:

1.A.G. Phadke and J.S. Thorp, " Computer Relaying for Power Systems", John Wiley and Sons, 1994
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POWER SYSTEM RELIABILITY

Module-I (10Hours)

Generating Capacity Basic Probability Methods: The generation system model, Loss of load indices, Equivalent forced outage rate, Capacity expansion analysis, Scheduled outages, Evaluation methods on period basis, Load forecast uncertainty, Forced outage rate uncertainty, Loss of energy indices.

Generating Capacity Frequency & Duration Method: The generation model, System risk indices.

Module-II (12 Hours)

Interconnected Systems: Probability error method in two interconnected systems, Equivalent assisting unit approach to two interconnected systems, Factors affecting the emergency assistance available through the interconnections, Variable reserve versus maximum peak load reserve, Reliability evaluation in three interconnected system, multi connected system, Frequency & duration approach.

Operating Reserve: General concepts, PJM method, Extension to PJM method, Modified PJM method, Postponable outages, Security function approach, Response risk, Interconnected systems.

Module-III (10 Hours)

Composite Generation & Transmission Systems: Radial configurations, Conditional probability approach, Network configurations, State selection, System & load point indices, Application to practical systems, Data requirements for composite system reliability.

Plant & Station Availability: Generating plant availability, Derated states & auxiliary systems, Allocation & effect of spares, Protection systems, HVDC systems.

Module-IV (11 Hours)

Distribution Systems Basic Techniques & Radial Networks: Evaluation techniques, additional interruption indices, Application to radial systems, effect of lateral distributor protection, Effect of disconnects, Effect of protection failures, effect of transferring loads, Probability distributions of reliability indices.

Distribution Systems-Parallel & Meshed Networks: Basic evaluation techniques, Inclusion of busbar failures, Inclusion of scheduled maintenance, Temporary & transient failures, Inclusion of weather effects, Common modes failures, Common mode failures & weather effects, Inclusion of breaker failures.

Text Books :

1.Billinton Roy& Allan Ronald "Reliability of Power system", Pitman Pub. 1984

2.Richard Elect. Brown, "Electric Power Distribution Reliabilty", CRC Press

ADVANCED CONTROL SYSTEMS

Module-I : (10 Hours)

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

Module -II : (12 Hours)

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

Module - III : (11 Hours)

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

Module - IV : (10 Hours)

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

Text/References:

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

ENERGY GENERATION FROM WASTE

MODULE-I:

Solid Waste Sources Solid Waste Sources, types, composition, Properties, Municipal Solid Waste: Physical, chemical and biological properties , Waste Collection and, Transfer stations, Waste minimization and recycling of municipal waste, Segregation of waste, Size Reduction , Managing Waste.

MODULE-II:

Status of technologies for generation of Energy from Waste Waste Treatment and Disposal Aerobic composting, incineration, Furnace type and design, Medical waste /Pharmaceutical waste treatment Technologies, incineration, Environmental impacts, Measures to mitigate environmental effects due to incineration.

MODULE-III:

Land Fill method of Solid waste disposal Land fill classification, Types, methods and Sitting consideration, Layout and preliminary design of landfills: Composition, characteristics, generation, Movement and control of landfill leachate and gases, Environmental monitoring system for land fill gases.

MODULE-IV:

Energy Generation from Waste Bio-chemical Conversion: Sources of energy generation, Anaerobic digestion of sewage and municipal wastes, Direct combustion of MSW-refuse derived solid fuel, Industrial waste, agro residues, Anaerobic Digestion: Biogas production, Land fill gas generation and utilization, Thermo-chemical conversion: Sources of energy generation, Gasification of waste using Gasifiers , Briquetting, Utilization and advantages of briquetting, Environmental benefits of Bio-chemical and Thermo- chemical conversion .

Text Books/References:

1. Nicholas P. Cheremisinoff. Handbook of Solid Waste Management and Waste Minimization Technologies.An Imprint of Elsevier, New Delhi (2003).
2. P. AarneVesilind, William A. Worrell and Debra R. Reinhart.Solid Waste Engineering. Thomson Asia Pte Ltd. Singapore (2002)
3. M. Dutta , B. P. Parida, B. K. Guha and T. R. Surkrishnan. Industrial Solid Waste Management and Landfilling practice. Narosa Publishing House, New Delhi (1999).
4. AmalenduBagchi. Design, construction and Monitoring of Landfills.John Wiley and Sons. New York. (1994)
5. M. L. Davis and D. A. Cornwell.Introduction to environmental engineering.McGraw Hill International Edition, Singapore (2008)
6. C. S. Rao. Environmental Pollution Control Engineering.Wiley Eastern Ltd. New Delhi (1995)
7. S. K. Agarwal. Industrial Environment Assessment and Strategy. APH Publishing Corporation. New Delhi (!996)
8. Sofer, Samir S. (ed.), Zaborsky, R. (ed.), “Biomass Conversion Processes for Energy and Fuels”, New York, Plenum Press, 1981
9. Hagerty, D.Joseph; Pavoni, Joseph L; Heer, John E., “Solid Waste Management”, New York, Van Nostrand, 1973

10. George Tchobanoglous, Hilary Theisen and Samuel Vigil Prsl: Tchobanoglous, George Theisen, Hillary Vigil, Samuel, "Integrated Solid Waste management: Engineering Principles and Management issues", New York, McGraw Hill, 1993
11. C Parker and T Roberts (Ed), Energy from Waste - An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985
12. KL Shah, Basics of Solid and Hazardous Waste Management Technology, Prentice Hall, 2000
13. M Datta, Waste Disposal in Engineered Landfills, Narosa Publishing House, 1997
14. G Rich et.al, Hazardous Waste Management Technology, Podvan Publishers, 1987
15. AD Bhide, BB Sundaresan, Solid Waste Management in Developing Countries, INSDOC, New Delhi,1983

POWER QUALITY IMPROVEMENT TECHNIQUES

Module-I : (15 Hours)
Concept of Power Quality: Frequency variations, voltage variations- sag and swell,waveform distortion –dc offset,harmonics, inter-harmonics, notching and noise. Fundamentals of Harmonics: Representation of harmonics,waveform, harmonic power, measures of harmonic distortion;Current and voltage limits of harmonic distortions: IEEE, IEC, EN,NORSOK.
Causes of Harmonics: 2-pulse, 6-pulse and 12-pulse converter configurations, input current waveforms and their harmonic spectrum; Input supply harmonics of AC regulator, integral cycle control, cycloconverter, transformer, rotating machines, ARC furnace, TV and battery charger.
Module-II : (14 Hours)
Effect of Harmonics: Parallel and series resonance, effect of harmonics on static power plant – transmission lines, transformers,capacitor banks, rotating machines, harmonic interference withripple control systems, power system protection, consumer equipments and communication systems, power measurement. Elimination/ Suppression of Harmonics: High power factorconverter, multi-pulse converters using transformer connections(delta, polygon).
Passive Filters: Types of passive filters, single tuned and high passfilters, filter design criteria, double tuned filters, damped filters andtheir design.Active Power Filters: Compensation principle, classification ofactive filters by objective, system configuration, power circuit and control strategy.
Module-III : (15 Hours)
PWM Inverter: Voltage sourced active filter, current sourced active filter, constant frequency control, constant tolerance bandcontrol, variable tolerance band control. Shunt Active Filter: Single-phase active filter, principle of operation, expression for compensating current, concept of constant capacitor voltage control; Three-phase active filter: Operation, analysis and modelling; Instantaneous reactive power theory..Three-phase Series Active Filter: Principle of operation, analysis and modelling. Other Techniques: Unified power quality conditioner, voltagesource and current source configurations, principle of operation for sag, swell and flicker control.

Text/References:
1. Derek A. P., “Power Electronic Converter Harmonics”, IEEE Press. 1989
2. Arrillaga J., Smith B. C., Watson N. R. and Wood A. R., “PowerSystem Harmonic Analysis”, 2nd2008Ed., Wiley India.
3. Arthur R. B., “Power System Analysis”, 2nd Ed., Pearson Education. 2008
4. Arrillaga J., Braedlley D. A. and Bodger P. S., “Power System Harmonics”, John Wiley and Sons.1985
5. Dugan R. C., McGranaghan M. F. and Beaty H. W., Electrical Power System Quality”, McGraw-Hill International Book Company.1996
6. Sankaran C., “Power Quality”, CRC Press. 2001

POWER SYSTEM CONTROL AND INSTRUMENTATION

Module-1

Control of voltage, frequency and tie-line power flows, Q-V and P-f control loops. Mechanism of real and reactive power control.

Module-2

Net interchange tie line bias control.Optimal, sub-optimal and decentralised controllers.AGC in isolated and interconnected power systems, AGC with economic dispatch.Discrete mode AGC.

Module-3

Time error and inadvetent interchange correction techniques. On line computer control.Distributed digital control.Data acquisition systems.Emergency control, Preventive control, system wide optimization.

Module-4

SCADA.supervisory control, supervisory master stations, remote terminal units, communication links, SCADA systems applications in power networks. System measurements using SCADA and computer Control.

Text Books /References:

- Wood A. J. and Wollenberg B.F., " Power Generation, Operation and Control, John Wiley & Sons
- Kundur P. and Balu N. J., "Power System Stability and Control", EPRI Series, McGraw-Hill International Book Company.
- "Modern Power Station Practice, Volume F: Control and Instrumentation", British Electricity International, Peragmon Press.
- Cegrell T., "Power System Control Technology", Prentice Hall International Edition.
- Grainger J. J. and Stevenson W. D., "Power System Analysis", Tata McGraw-Hill Publishing Company Limited.
- Anderson P. M. and Fouad A. A., "Power system control and stability", IEEE Press.
- Ronald L. Krutz"Securing SCADA system"johnwilly publication.
- Fabiosaccomanno"Electric Power System Analysis and Control"IEEE Press
- AtifS. Debs,"Modern power systems control and operation",Kluwer academic publishers

ELECTRIC DRIVES IN HYBRID VEHICLE

Module-I : (11 Hours)

Introduction: History of hybrid vehicles, architectures of HEVs,series and parallel HEVs, complex HEVs. Hybridization of Automobile: Fundamentals of vehicle,components of conventional vehicle and propulsion load; Drivecycles and drive terrain; Concept of electric vehicle and hybrid electric vehicle; Plug-in hybrid vehicle, constituents of PHEV, comparison of HEV and PHEV; Fuel Cell Vehicles and itsconstituents.

Module-II : (10 Hours)

Plug-in Hybrid Electric Vehicle: PHEVs and EREVs, blended PHEVs,PHEVArchitectures,equivalent electric range of blendedPHEVs; Fuel economy of PHEVs, power management of PHEVs,end-of-life battery for electric power grid support, vehicle to grid technology, PHEV battery charging.

Module-III : (10 Hours)

Power Electronics in HEVs: Rectifiers used in HEVs, voltage ripples; Buck converter used in HEVs, non-isolated bidirectional DC-DC converter, regenerative braking, voltage source inverter,current source inverter, isolated bidirectional DC-DC converter, PWM rectifier in HEVs, EV and PHEV battery chargers.

Module-IV: (11 Hours)

Electric Machines and Drives in HEVs: Induction motor drives, Field oriented control of induction machines; Permanent magnet motor drives; Switched reluctance motors; Doubly salientpermanent magnet machines.

Text Books/References:

1. Pistooa G., “Power Sources , Models, Sustanability, Infrstructure and the market”, Elsevier 2008

2. Mi Chris, Masrur A., and Gao D.W., “ Hybrid Electric Vehicle: Principles and Applications with Practical Perspectives”1995

GREEN ENERGY RESOURCES & TECHNOLOGY

Module-I :

Solar photovoltaics: Introduction, Solar cell characteristics, Losses in solar cells, Modeling of solar cell, Solar PV modules, Bypass diode in PV module, Design of PV module, PV module power output, I-V curve of PV module, BOS of PV module, Batteries for solar PV, Battery charge controllers, DC-DC converters, DC-AC converters, MPPT, Different algorithm for MPPT, Types of PV system, Performance analysis of solar cell, Working of solar cell power plant.

Module-II :

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

Ocean Energy: Ocean energy resources-ocean energy routes - Principles of ocean thermal energy conversion systems- ocean thermal power plants- Principles of ocean wave energy conversion and tidal energy conversion.

Module-III :

Biomass Energy: Introduction, Biomass conversion technology, Biogas, Composition of Biogas, Properties of Biogas, Biogas production reaction, Factor affecting biogas production, Biogas plant site selection, Biogas plants, Types of Biogas plants, Biogas purification, Biogas storage, Biogas dispensing, Advantages and disadvantages of Biogas, Emission from Biogas engines, Digester Filling and Biogas plant operation, Biogas digester sizing.

Module-IV :

Hybrid Power SyStems: Introduction, Need for hybrid systems, Range of hybrid systems, Types of Hybrid systems, Diesel-PV system, Wind-PV system, Micro hydel-PV system, Biomass-PV system, Electric vehicles, Hybrid electric vehicles.

Energy Conservation, Management and Economics: Impact of renewable energy on environment, Principle and strategies of energy conservation, energy management, energy audit, energy planning, Total energy system concept, Power tariff, Cost of electricity production from renewable.

Text/Reference Books:

1. S. N. Bhadra, D. Kastha, S. Banerjee, *Wind Electrical Systems*: Oxford Univ. Press, 2005.
2. S. S. Thipse, Non Conventional and Renewable Energy Sources, Narosa Publishing House, 2014.
3. S.A. Abbasi, N. Abbasi, *Renewable Energy Sources and Their Environmental Impact:* Prentice Hall of India, 2004.
4. S.P. Sukhatme - Solar Energy: Principles of thermal Collection and Storage,TMH,New Delhi
5. Duffic and Beckman - Solar Engineering of Thermal Processes, John wiley
6. Green Management and Green Technologies: Exploring the Causal Relationship by Jazmin Seijas Nogarida,2008.
7. Green Marketing and Management: A global Perspective by John F. Whaik, 2005

QUANTITATIVE METHODS FOR ENERGY MANAGEMENT & PLANNING

MODULE-I:

A review of probability concepts, Forecasting and decision making in view of multi-variant techniques, Linear programming, Graphical solution, Simplex method, Duality and post-optimality analysis, Integer programming .

MODULE-II:

Optimal technology mix in micro and macro level energy planning exercises, Sequencing, Queuing theory, Networks, PERT and CPM,

MODULE-III:

Decision theory, Markov analysis, Non linear programming, Decision making with uncertainty, decision making with multiple objectives, Deterministic and probabilistic dynamic programming, Regression analysis.

Text/References

1. Operations Research, An Introduction, Sixth Edition, 2000, by HA Taha, Prentice-Hall of India Pvt. Ltd.

2. Quantitative Techniques in Management, First Edition, 1997, by ND Vohra, Tata McGraw-Hill Publishing Company Ltd, New Delhi.

Advanced Numerical Methods

Module 1: Introduction to digital computers & Programming - an overview; Errors - polynomial approximations and interpolations - Numerical differentiation & Integration.

Module 2: Evaluation of single and multiple integrals, Newton's method, variational and weightened residual methods. Matrices – Linear equations, Eigenvalues and Eigenvectors - nonlinear equations.

Module 3: Harmonic and biharmonic equations - solutions, convergence, completeness & stability.

Module 4: Initial and boundary value problems of finite difference method, Implicit & Explicit scheme.

References

1. Jain M.K, SRK Iyenge and RK Jain."Numerical Methods for Scientific &Engg.Computation".
2. Mathews J. H "Numerical Methods for Mathematics, Science and Engineering".
3. Gerld C.F and PO Wheatley "Applied Numerical Analysis".
4. Gupta S.C and V. K. Kapoor "Fundamentals of Applied Statistic", Sultan Chand & Sons.
5. Johnson R.A " Probability and Statistics for Mngineers.
6. Rajeshwaran S, "Numerical Methods in Science & Engineering (A Practical Approach)" , Willey Publication.

LAB-2

(To Be Decided By The Dept.)

Specialization: Energy System Engineering

Second Semester							
Theory					**Practical**		
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Solar Energy Engineering	4-0	4	100	50	-	-	-
Specialization Core-2 Wind and Small Hydro System	4-0	4	100	50	-	-	-
Elective I(Specialization related) 1.HVDC Transmission & FACTS 2.Operation & control of Electrical Energy System 3.Energy System Modelling & Analysis 4.Energy Resources, Economics & Environment	4-0	4	100	50	-	-	-
Elective II(Departmental related) 1.Power System Planning & Operation 2.Energy Generation From Waste 3.Computer Aided Power System Analysis 4.Power System Control & Instrumentation	4-0	4	100	50	-	-	-
Elective III(from any department) 1.Electric Drives In Hybrid Vehicles 2.Green Energy Resources & Technology 3.Quantitative methods For Energy Management & Planning 4.System Identification & Adaptive Control	4-0	4	100	50	-	-	-
Lab-2 (Specialization lab to be decided by the department)					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

SOLAR ENERGY TECHNOLOGY

MODULE-I:

Solar Photovoltaic (SPV) Systems: Source of radiation – solar constant– solar charts Measurement of diffuse, global and direct solar radiation, Photovoltaic Effect, Multi-junction solar cell, Quantum well solar cell, thin film solar cells, Equivalent Circuit of the Solar Cell, Analysis of PV Cells: Dark and illumination characteristics.

MODULE-II:

Figure of merits of solar cell, Efficiency limits, Variation of efficiency with band-gap and temperature, Efficiency measurements, Solar array, Voltage regulation, Maximum tracking. Solar Thermal Systems: Flat Plate Collectors.

MODULE-III:

Energy balance principle, Overall Heat Loss Coefficient , heat transfer between Parallel surfaces , Heat capacity effect, Types of Flat Plate Collectors: Liquid Flat Plate Collectors, Air flat-plate Collectors-Thermal analysis, Evacuated tubular collectors, Solar Energy Storage, Collector tracking systems.

MODULE-IV:

Applications of Solar PV and Solar Thermal Systems: Centralized and decentralized SPV systems, Stand alone, hybrid, and grid connected SPV systems. Solar Passive Heating and Cooling, Solar Thermal Power Plant, Solar Desalination, Solar Drying, Solar Cooking, Solar Greenhouse technology, Application of solar thermal energy in agriculture and space heating.

Texts Books/References:

1. SP Sukhatme, Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw-Hill,1984
2. JA Duffie and WA Beckman, Solar Engineering of Thermal Processes, John Wiley, 1991
3. B Sorensen, Renewable Energy, (2nd Ed), Academic press, New York, 2000
4. Garg HP, J Prakash, Solar Energy: Fundamentals and Applications, Tata McGraw Hill, New Delhi, 1997
5. DY Goswami, F Kreith and JF Kreider, Principles of Solar Engineering,Taylor and Francis
6. GN Tiwari, S Suneja, Solar Thermal Engineering System, Narosa Publishing House, New Delhi, 1997
7. AL Fahrenbruch and RH Bube, Fundamentals of Solar Cells: PV Solar Energy Conversion, Academic Press, New York, 1983
8. T Bhattacharya, Terrestrial Solar Photovoltaic, Narosa Publishers Ltd, New Delhi LD Partain (ed), Solar Cells and their Applications, John Wiley and Sons, Inc, New York, 1995
9. RH Bube, Photovoltaic Materials, Imperial College Press, 1998
10. HS Rauschenbach, Solar Cell Array Design Handbook, Van NostrandReinfold Company, New York, 1980
11. R Messenger and J Vnetre, Photovoltaic Systems Engineering, CRC Press Stand Alone PV Systems: A Handbook of Recommended Design Practices, Report No SAND 87-7023, Sandia National Lab USA 11
12. F Kreith and JF Kreider, Principles of Solar Engineering, McGraw-Hill (1978)
13. J Twidell and T Weir, Renewable Energy Resources, Taylor and Francis (Ed), New York, USA, 2006

WIND AND SMALL HYDRO SYSTEMS

MODULE-I:

Wind Energy Fundamentals

Wind Energy Basics, Wind Speeds and scales, Terrain, Roughness, Wind Mechanics,Power Content,Instrumentation for wind measurements, Wind data analysis, tabulation, Wind resource estimation, Betz'sLimit, Turbulence.

MODULE-II:

Classification of wind turbines

Vertical Axis Type, Horizontal Axis, Constant Speed Constant Frequency, Variable speed VariableFrequency, Up Wind, Down Wind, Stall Control, Pitch Control and Gear Coupled Generator type windturbines.

MODULE-II:

Modern Wind Turbine Control

Gear Coupled Generator Wind Turbine, Direct Rotor Coupled Generator Wind Turbine**,** Excited RotorSynchronous Generator / PMG Generator, Control Rectifier, Capacitor Banks, Step Up / Boost Converter (DC-DC Step Up), Grid Tied Inverter, Power Management, Grid Monitoring Unit (Voltage and Current),Transformer, Safety Chain Circuits, Doubly Fed Induction Generator and Power Control

MODULE-III:

Small Hydro and Hybrid Systems:

Overview of micro mini and small hydro, Site selection and civil works, Penstocks and turbines, Speed andvoltage regulation, Investment issues, load management and tariff collection, Distribution and marketingissues, Hydro based stand-alone / hybrid power systems, Control of hybrid power systems, case studies

TEXT BOOKS

1. S. Rao & B. B. Parulekar, "Energy Technology", 4th edition, Khanna publishers, 2005.
2. Wind energy Handbook, Edited by T. Burton, D. Sharpe, N. Jenkins and E. Bossanyi,
1. John Wiley & Sons, 2001
2. Wind and Solar Power Systems, Mukund. R. Patel, 2nd Edition, Taylor & Francis, 2001
3. L .L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.
4. D. A. Spera, Wind Turbine Technology: Fundamental concepts of Wind Turbine
5. Engineering, ASME Press

REFERENCES

1. *Anna Mani & Nooley, "Wind Energy Data for India", 1983.*
2. *IS 875 Part IV and IS 1893 semics D+STDS mareials STDS IS 226 (IS 2862, ASTMS 36,*
3. *BS 4360 GR 43D and A).*
4. *Logan (EARL),"Turbo Machinery Basic theory and applications", 1981.*
5. Wind Energy Explained – Theory, Design and Application by J. F. Manwell, J. G. McGowan and A. L.

6. Rogers, John Wiley & Sons, Ltd., 2002
7. Aerodynamics of Wind turbines by Martin O. L. Hansen, Earthscan, 2008.
8. Wind Turbine Control Systems- Principles, Modelling and Gain Scheduling Design by Fernando D.
9. Bianchi, Hernan De Battista and Ricardo J. Mantz, Springer, 2007
10. Micro-Hydro Design Manual: A Guide to Small-Scale Water Power Schemes by Adam Harvey, Andy
11. Brown and Priyantha Hettiarachi ITDG,1993.
12. Guide on How to Develop a Small Hydropower Plant by Maria Laguna, ESHA,2004
13. Good & Bad of Mini Hydro Power edited by Roman Ritter, GTZ, 2009

HVDC TRANSMISSION& FACTS

Module-I(10hours)

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

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

Module-II :(11hours)

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

Module-III:(15hours)

FACTS Concept and General System:

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

Module-IV:(15hours)

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

Text/References:

1. Padiyar K.R., "HVDC Power Transmission System", Wiely Eastern PVT Limited
2. Kimbark, "Direct Current transmission", Vol.1, John Wielly, New York, 1971
3. Understanding FACTS: Cocepts and Technology of Flexible AC Transmission Systems. By N. G. Hingorani and L. Gyugi, Standard Publisher Distributors, IEEE Press, Delhi
4. Flexible AC Transmission Systems. By J. Arillage 13

OPERATION & CONTROL OF ELECTRICAL ENERGY SYSTEMS

MODULE-I:

Real Time Monitoring of Power Systems : State Estimation, Topological observability Analysis, Security Analysis of Power Systems, Economic Dispatch & Unit Commitment

MODULE-II:

Control of Power & Frequency : Turbine -Governor Control Loops, Single Area and Multi-Area Systems Control, Effect of high penetration of Wind & Other Renewable/Distributed Generation on P-F Control.

MODULE-III:

Control of Voltage & Reactive Power: Generator Excitation Systems, & Automatic Voltage Regulators, Transformer Tap Changes Controls, Voltage Control in Distribution Networks using New Power Electronic Devices.

MODULE-IV:

Introduction to Market operations in Electric Power Systems : Restructured Power Systems, Short Term Load Forecasting, Power Trading through Bilateral, Multilateral Contracts and Power Exchanges, Role of Distributed Generators in market Operations.

TEXT BOOKS

1. Wood, A.J. and B.F. Wollenberg, Power Generation Operation and Control, Wiley – IntersciencePublication, Second Ediction (2003).
2. O.I. Elgard, Electric Energy Systems Theory : An Introductuion, Tata McGraw Hill Publication, SecondEdition, 1982
3. Shahidepour, M. et al, Market Operationhs in Electric Power Systems, Wiley Interscience & IEEEPublication, 2002.
4. Bhattacharya et al, Operation of Restructured Power Systems, Kluwer Academic Publishers, 2001.

ENERGY SYSTEM MODELING AND ANALYSIS

MODULE-I:

Modeling overview:

Input output analysis, steps in model development, examples of models. Quantitative Techniques:Interpolation-polynomial, Lagrangian. Curve-fitting, Systems Simulation-information flow diagram, solutionof set of nonlinear algebraic equations, successive substitution,

MODULE-II:

Newton Raphson Method Analysis of System load curve, plant load factor, availability, Loss of load Probability calculations for a power system.

Optimisation :

Objectives/constraints, problem formulation. Unconstrained problems- Necessary & Sufficiency conditions,Constrained Optimisation- Lagrange multipliers, constrained variations, Kuhn-Tucker conditions.

MODULE-III:

Linear Programming - Simplex tableau, pivoting, sensitivity analysis. Dynamic Programming. Search Techniques-Univariate / Multivariate. Case studies of optimisation in Energy systems problems. Dealing with uncertaintyprobabilistic techniques. Trade-offs between capital & energy using Pinch Analysis.

MODULE-IV:

Basic concept of econometrics and statistical analysis:

The 2-variable regression model; The multiple regression model; Tests of regression coefficients andregression equation, Econometric Energy Demand Modeling,Econometric techniques used for energy demandanalysis, Methodology for Energy Forecasting- Sectoral Energy Demand Forecasting, Load Forecasting –Timeseries, Econometric, end use techniques.

Text/References

1. S.S.Rao Optimisation theory and applications, Wiley Eastern, 1990
2. S.S. Sastry Introductory methods of numerical analysis,Prentice Hall, 1988
3. P. Meier Energy Systems Analysis for Developing Countries, Springer Verlag, 1984
4. R.de Neufville, Applied Systems Analysis, Mcgraw Hill, International Edition, 1990
5. Beveridge and Schechter,Optimisation Theory and Practice,Mcgraw Hill, 1970
6. B.K. Hodge: Analysis and Design of Energy Systems, Prentice Hall, 1990.
7. W.J. Gajda and W.E. Biles: Engineering Modeling and Computation, Houghton Mifflin, 1980.
8. R.W.Haywood, Analysis of Engineering Cycles, 4th Edition, Pergamon Press, Oxford, 1991.
9. H.G. Stoll, Least Cost Electrical Utility / Planning, John Wiley & Sons, 1989.
10. T.M. O' Donovan, Short Term Forecasting: An introduction to the Box Jenkins Approach, Wiley,
11. Chichester,1983.
12. Wood, A.J., Wollenberg, B.F., Power Generation, operation & control, John Wiley, New York, 1984.

ENERGY RESOURCES, ECONOMICS & ENVIRONMENT
(Will be uploaded soon)

POWER SYSTEM PLANNING AND OPERATION

MODULE-I:

Demand Forecasting and Generation Planning: Sector-wise peak demand and energy forecasting by trendand econometric projection methods.

Probabilistic models of generating unit outage performance and system load, Evaluation of loss of load andloss of energy indices, Probabilistic production costing, Inclusion of renewable energy sources in thereliability analysis.

MODULE-II:

Interconnected Systems: Multi-area reliability analysis, Power pool operation and power/energy exchange
contracts, Quantification of economic and reliability benefits by pool operation.

MODULE-III:

Optimal Generation Expansion Planning : Formulation of least cost optimization problem incorporatingthe capital, operating and maintenance costs of candidate plants of different types (thermal, hydro, nuclear,renewables etc) and minimum assured reliability constraints,

MODULE-IV:

Optimization techniques for solution by linear,nonlinear and dynamic programming approaches, Case studies.

Text Books /References:

1. Power Generation, Operation, and Control by Allen J. Wood and Bruce F. Wollenberg, John Wiley & Sons,
1. 2003.
2. Power System Control and Stability by P. M. Anderson and A. A. Fouad, Wiley-IEEE Press, 2002
3. Electric Energy Systems Theory: An Introduction by Olle I Elgerad, T M H Edition, 1982
4. HVDC Transmission: Power Conversions Applications in Power Systems by Chan-Ki Kim, Vijay K. Sood,
5. Gil-Soo Jang, Seong-Joo Lim, Seok-Jin Lee, Wiley – IEEE Press, 2009
6. Electric Power Transmission System Engineering Analysis and Design by Turan Gonen, CRC Press, 2009
7. Power System Stability and Control by P. Kundur, McGraw-Hill, 1994

ENERGY GENERATION FROM WASTE

MODULE-I:

Solid Waste Sources Solid Waste Sources, types, composition, Properties, Municipal Solid Waste: Physical, chemical and biological properties , Waste Collection and, Transfer stations, Waste minimization and recycling of municipal waste, Segregation of waste, Size Reduction , Managing Waste.

MODULE-II:

Status of technologies for generation of Energy from Waste Waste Treatment and Disposal Aerobic composting, incineration, Furnace type and design, Medical waste /Pharmaceutical waste treatment Technologies, incineration, Environmental impacts, Measures to mitigate environmental effects due to incineration.

MODULE-III:

Land Fill method of Solid waste disposal Land fill classification, Types, methods and Sitting consideration, Layout and preliminary design of landfills: Composition, characteristics, generation, Movement and control of landfill leachate and gases, Environmental monitoring system for land fill gases.

MODULE-IV:

Energy Generation from Waste Bio-chemical Conversion: Sources of energy generation, Anaerobic digestion of sewage and municipal wastes, Direct combustion of MSW-refuse derived solid fuel, Industrial waste, agro residues, Anaerobic Digestion: Biogas production, Land fill gas generation and utilization, Thermo-chemical conversion: Sources of energy generation, Gasification of waste using Gasifiers , Briquetting, Utilization and advantages of briquetting, Environmental benefits of Bio-chemical and Thermo- chemical conversion .

Text Books/References:

1. Nicholas P. Cheremisinoff. Handbook of Solid Waste Management and Waste Minimization Technologies.An Imprint of Elsevier, New Delhi (2003).
2. P. AarneVesilind, William A. Worrell and Debra R. Reinhart.Solid Waste Engineering. Thomson Asia Pte Ltd. Singapore (2002)
3. M. Dutta , B. P. Parida, B. K. Guha and T. R. Surkrishnan. Industrial Solid Waste Management and Landfilling practice. Narosa Publishing House, New Delhi (1999).
4. AmalenduBagchi. Design, construction and Monitoring of Landfills.John Wiley and Sons. New York. (1994)
5. M. L. Davis and D. A. Cornwell.Introduction to environmental engineering.McGraw Hill International Edition, Singapore (2008)
6. C. S. Rao. Environmental Pollution Control Engineering.Wiley Eastern Ltd. New Delhi (1995)
7. S. K. Agarwal. Industrial Environment Assessment and Strategy. APH Publishing Corporation. New Delhi (!996)
8. Sofer, Samir S. (ed.), Zaborsky, R. (ed.), “Biomass Conversion Processes for Energy and Fuels”, New York, Plenum Press, 1981
9. Hagerty, D.Joseph; Pavoni, Joseph L; Heer, John E., “Solid Waste Management”, New York, Van Nostrand, 1973

10. George Tchobanoglous, Hilary Theisen and Samuel Vigil Prsl: Tchobanoglous, George Theisen, Hillary Vigil, Samuel, “Integrated Solid Waste management: Engineering Principles and Management issues”, New York, McGraw Hill, 1993
11. C Parker and T Roberts (Ed), Energy from Waste - An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985
12. KL Shah, Basics of Solid and Hazardous Waste Management Technology, Prentice Hall, 200
13. M Datta, Waste Disposal in Engineered Landfills, Narosa Publishing House, 1997
14. G Rich et.al, Hazardous Waste Management Technology, Podvan Publishers, 1987
15. AD Bhide, BB Sundaresan, Solid Waste Management in Developing Countries, INSDOC, New Delhi,1983

COMPUTER AIDED POWER SYSTEM ANALYSIS

(Will be uploaded soon)

POWER SYSTEM CONTROL AND INSTRUMENTATION

Module-I

Control of voltage, frequency and tie-line power flows, Q-V and P-f control loops. Mechanism of real and reactive power control.

Module-II

Net interchange tie line bias control.Optimal, sub-optimal and decentralised controllers.AGC in isolated and interconnected power systems, AGC with economic dispatch.Discrete mode AGC.

Module-III

Time error and inadvetent interchange correction techniques. On line computer control.Distributed digital control.Data acquisition systems.Emergency control, Preventive control, system wide optimization.

Module-IV

SCADA.supervisory control, supervisory master stations, remote terminal units, communication links, SCADA systems applications in power networks. System measurements using SCADA and computer Control.

Reference Books:

1. Wood A. J. and Wollenberg B.F., " Power Generation, Operation and Control, John Wiley & Sons
2. Kundur P. and Balu N. J., "Power System Stability and Control", EPRI Series, McGraw-Hill International Book Company.
3. "Modern Power Station Practice, Volume F: Control and Instrumentation", British Electricity International, Peragmon Press.
4. Cegrell T., "Power System Control Technology", Prentice Hall International Edition.
5. Grainger J. J. and Stevenson W. D., "Power System Analysis", Tata McGraw-Hill Publishing Company Limited.
6. Anderson P. M. and Fouad A. A., "Power system control and stability", IEEE Press.
7. Ronald L. Krutz"Securing SCADA system"johnwilly publication.
8. Fabiosaccomanno"Electric Power System Analysis and Control"IEEE Press
9. AtifS. Debs,"Modern power systems control and operation",Kluwer academic publishers

ELECTRIC DRIVES IN HYBRID VEHICLE

Module-I : (11 Hours)

Introduction: History of hybrid vehicles, architectures of HEVs,series and parallel HEVs, complex HEVs. Hybridization of Automobile: Fundamentals of vehicle,components of conventional vehicle and propulsion load; Drivecycles and drive terrain; Concept of electric vehicle and hybrid electric vehicle; Plug-in hybrid vehicle, constituents of PHEV, comparison of HEV and PHEV; Fuel Cell Vehicles and itsconstituents.

Module-II : (10 Hours)

Plug in Hybrid Electric Vehicle: PHEVs and EREVs, blended PHEVs,PHEVArchitectures,equivalent electric range of blendedPHEVs; Fuel economy of PHEVs, power management of PHEVs,end-of-life battery for electric power grid support, vehicle to grid technology, PHEV battery charging.

Module-III : (10 Hours)

Power Electronics in HEVs: Rectifiers used in HEVs, voltage ripples; Buck converter used in HEVs, non-isolated bidirectional DC-DC converter, regenerative braking, voltage source inverter,current source inverter, isolated bidirectional DC-DC converter, PWM rectifier in HEVs, EV and PHEV battery chargers.

Module-IV: (11 Hours)

Electric Machines and Drives in HEVs: Induction motor drives, Field oriented control of induction machines; Permanent magnet motor drives; Switched reluctance motors; Doubly salientpermanent magnet machines.

Suggested Books:

1. Pistooa G., “Power Sources , Models, Sustanability, Infrstructure and the market”, Elsevier 2008
2. Mi Chris, Masrur A., and Gao D.W., “ Hybrid Electric Vehicle: Principles and Applications with Practical Perspectives”1995

GREEN ENERGY RESOURCES & TECHNOLOGY

Module-I :

Solar photovoltaics: Introduction, Solar cell characteristics, Losses in solar cells, Modeling of solar cell, Solar PV modules, Bypass diode in PV module, Design of PV module, PV module power output, I-V curve of PV module, BOS of PV module, Batteries for solar PV, Battery charge controllers, DC-DC converters, DC-AC converters, MPPT, Different algorithm for MPPT, Types of PV system, Performance analysis of solar cell, Working of solar cell power plant.

Module-II :

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

Ocean Energy: Ocean energy resources-ocean energy routes - Principles of ocean thermal energy conversion systems- ocean thermal power plants- Principles of ocean wave energy conversion and tidal energy conversion.

Module-III :

Biomass Energy: Introduction, Biomass conversion technology, Biogas, Composition of Biogas, Properties of Biogas, Biogas production reaction, Factor affecting biogas production, Biogas plant site selection, Biogas plants, Types of Biogas plants, Biogas purification, Biogas storage, Biogas dispensing, Advantages and disadvantages of Biogas, Emission from Biogas engines, Digester Filling and Biogas plant operation, Biogas digester sizing.

Module-IV :

Hybrid Power Syatems: Introduction, Need for hybrid systems, Range of hybrid systems, Types of Hybrid systems, Diesel-PV system, Wind-PV system, Micro hydel-PV system, Biomass-PV system, Electric vehicles, Hybrid electric vehicles.

Energy Conservation, Management and Economics: Impact of renewable energy on environment, Principle and strategies of energy conservation, energy management, energy audit, energy planning, Total energy system concept, Power tariff, Cost of electricity production from renewable.

Text/Reference Books:

1. S. N. Bhadra, D. Kastha, S. Banerjee, *Wind Electrical Systems*: Oxford Univ. Press, 2005.
2. S. S. Thipse, Non Conventional and Renewable Energy Sources, Narosa Publishing House, 2014.

3. S.A. Abbasi, N. Abbasi, *Renewable Energy Sources and Their Environmental Impact:* Prentice Hall of India, 2004.
4. S.P. Sukhatme - Solar Energy: Principles of thermal Collection and Storage,TMH,New Delhi
5. Duffic and Beckman - Solar Engineering of Thermal Processes, John wiley
6. Green Management and Green Technologies: Exploring the Causal Relationship by Jazmin Seijas Nogarida,2008.
7. Green Marketing and Management: A global Perspective by John F. Whaik, 2005

QUANTITATIVE METHODS FOR ENERGY MANAGEMENT & PLANNING

MODULE-I:
A review of probability concepts, Forecasting and decision making in view of multi-variant techniques, Linear programming,

MODULE-II:
Graphical solution, Simplex method, Duality and post-optimality analysis, Integer programming .

MODULE-III:
Optimal technology mix in micro and macro level energy planning exercises, Sequencing, Queuing theory, Networks, PERT and CPM,

MODULE-IV:
Decision theory, Markov analysis, Non linear programming, Decision making with uncertainty, decision making with multiple objectives, Deterministic and probabilistic dynamic programming, Regression analysis.

Text/References

1. Operations Research, An Introduction, Sixth Edition, 2000, by HA Taha, Prentice-Hall of India Pvt. Ltd.
2. Quantitative Techniques in Management, First Edition, 1997, by ND Vohra, Tata McGraw-Hill Publishing Company Ltd, New Delhi.

SYSTEM IDENTIFICATION AND ADAPTIVE CONTROL

Module-I (12 Hours)

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

Module-II (12 Hours)

Recursive Identification of Linear dynamic systems: RLS, ELS, IV, RML, Stochastic Approximation, Extended Kalman Filter, generalized prediction error framework and its application to ARMA and state models, convergence analysis, Time varying parameters. Nonlinear System Identification. ; Adaptive schemes. Adaptive control theory. Applications. Situations when constant Gain feedback is insufficient.

Module-III (12 Hours)

Robust control. ; The adaptive control problem. ; The model following problem. MRAS based on stability theory. Model following when the full state is measurable.
Direct MRAS for general linear systems. Prior knowledge in MRAS. MRAS for partially known systems. Use of robust estimation methods in MRAS. ; The basic idea. Indirect self-tuning regulators. Direct Self-tuning regulators.

Module-IV (12 Hours)

Linear Quadratic STR. Adaptive Predictive control. Prior knowledge in STR.; Linear-in-the-parameters model. Least squares estimation. Experimental conditions. Recursive estimators. Extended least squares. Robust estimation methods (dead zone, projection).Implementation issues. ; Nonlinear System Identification Techniques

Essential Readings:

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

Supplementary Reading:

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

Specialization: Power Engineering and Energy System/ Power And Energy Engineering

Second Semester								
Theory					Practical			
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**	
Specialization Core-1 Foundation For Energy Systems Technology	4-0	4	100	50	-	-	-	
Specialization Core-2 Power System Dynamics	4-0	4	100	50	-	-	-	
Elective I(Specialization related) 1.HVDC Transmission & FACTS 2.EHVAC Transmission 3.Operation & Control Of Electrical Energy Systems 4.Power System Reliability	4-0	4	100	50	-	-	-	
Elective II (Departmental related) 1.Advance Control System 2. Energy Generation From Waste 3.Power Quality Improvement Techniques 4.Protection & Digital Relaying	4-0	4	100	50	-	-	-	
Elective III(from any department) 1. Electric Drives In Hybrid Vehicle 2.Green Energy Resources & Technology 3. Quantitative methods For Energy Management & planning 4.System Identification & Adaptive Control	4-0	4	100	50	-	-	-	
Lab-2 (Specialization lab to be decided by the department)					4	4	150	
Seminar/Project					4	4	150	
Total								
Total Marks: 1050								
Total Credits: 28								

FOUNDATION FOR ENERGY SYSTEMS TECHNOLOGY

MODULE-I:

Renewable Energy Alternatives:
Solar Photovoltaic conversion, Wave Energy and Ocean Thermal Energy Conversion, Wind Energy Conversion, Biomass Energy Conversion, Energy from Waste, Mini/Micro-hydel

MODULE-II:

Basic Concepts of Thermodynamics:
First law and its application, second law and its application, Irreversibility and power generation cycles.
Basic Concepts of Heat transfer: Heat exchangers, overall heat transfer co-efficient, Design of single and multiple pass heat Exchangers, Heat Pipes, Heat Pumps and their applications in Solar Energy systems.

MODULE-III:

Basic Concepts of Fluid Mechanics:
Basic Concepts**,** Flow through pipes, Fluid flow in solar water heaters
Combustion Process Overview: Basic physical laws governing combustion, air as a source of oxygen for combustion, combustion principles of solid-liquid-gaseous fuels.

MODULE-IV:

Effiency Calculation:
Proximate and ultimate analysis of solid and gaseous fuels, Estimation of calorific values, combustion process, flame velocity, excess air requirements and estimation, flue gas analysis, combustion efficiency.

Text Books /References:

1. RE Sonntag, C Borgnakke, GJ Van Wylen, *Fundamentals of Thermodynamics*, 6th Edition, (Wiley-India)
2. PK Nag, *Engineering Thermodynamics*, Third Edition (*Tata McGraw-Hill)*
3. YA Cengel and MA Boles, *Thermodynamics: An Engineering Approach*, 6th Edition (Tata McGraw-Hill)
4. SR Turns, *An Introduction to Combustion: Concepts and Applications*, 2nd Edition (McGraw Hill)
5. JB Jones and RE Dugan, *Engineering Thermodynamics*, PHI, New Delhi,
6. SP Sukhatme, *Solar Energy - Principles of thermal collection and storage*, 2nd edition, Tata McGraw-Hill, New Delhi
7. JA Duffie and WA Beckman, *Solar Engineering of Thermal Processes*, 2nd edition, John Wiley, NY
8. DY Goswami, F Kreith and JF Kreider, *Principles of Solar Engineering*, Taylor and Francis, Philadelphia
9. M. W. Zemansky, *Heat and Thermodynamics*, 4th Edn. McGraw Hill, 1968.
10. A. L. Prasuhn, *Fundamentals of Fluid Mechanics*, Prentice Hall, 1980
11. S. P. Sukhatme, *A Text book on Heat Transfer*, Orient Longman, 1979.
12. John Twidell and Tony Weir, “Renewable Energy Resources” Second Edition, Taylor and Francis (2006)
13. G. N. Tewari and M. K. Ghosal, Renewable Energy Sources: Basic Principles and Applications, Narosa Publishing House (2005)

POWER SYSTEM DYNAMICS

Module-I (12 Hours)

Power System Stability Problems: Basic concepts and definitions, Rotor angle stability, Synchronous machine characteristics, Power versus angle relationship, Stability phenomena, Voltage stability and voltage collapse, Mid-term and long-term stability, Classification of stability.
Small Signal Stability: State space concepts, Basic linearization technique, Participation factors, Eigen properties of state matrix, small signal stability of a single machine infinite bus system,

Module-II (10 Hours)

Studies of parametric effect: effect of loading, effect of K_A, effect of type of load, Hopf bifurcation, Electromechanical oscillating modes, Stability improvement by power system stabilizers. Design of power system stabilizers.
Large Perturbation Stability: Transient stability: Time domain simulations and direct stability analysis techniques (extended equal area criterion)

Module-II (10 Hours)

Energy function methods: Physical and mathematical aspects of the problem, Lyapunov's method, Modeling issues, Energy function formulation, Potential Energy Boundary Surface (PEBS): Energy function of a single machine infinite bus system, equal area criterion and the energy function, Multimachine PEBS.
Sub Synchronous Oscillations: Turbine generator torsional characteristics, Shaft system model, Torsional natural frequencies and mode shapes,

Module-III (12 Hours)

Torsional interaction with power system controls: interaction with generator excitation controls, interaction with speed governors, interaction with nearby DC converters,
Sub Synchronous Resonance (SSR): characteristics of series capacitor – compensated transmission systems, self – excitation due to induction generator effect, torsional interaction resulting in SSR, Analytical methods, Counter measures to SSR problems. Voltage stability, System oscillations

References:

1. Prabha. Kundur, *Power system stability and control*, Tata McGraw-Hill, 1994
2. P. Sauer and M. Pai, *Power system dynamics and stability*, Prentice Hall, 1998. 12

HVDC TRANSMISSION & FACTS

Module-I(10hours)

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

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

Module-II :(11hours)

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

Module-III:(15hours)

FACTS Concept and General System:

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

Module-IV:(15hours)

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

Text/References:

1. Padiyar K.R., "HVDC Power Transmission System", Wiely Eastern PVT Limited
2. Kimbark, "Direct Current transmission", Vol.1, John Wielly, New York, 1971
3. Understanding FACTS: Cocepts and Technology of Flexible AC Transmission Systems. By N. G. Hingorani and L. Gyugi, Standard Publisher Distributors, IEEE Press, Delhi
4. Flexible AC Transmission Systems. By J. Arillage 13

EHVAC TRANSMISSIONS

Module- I (10 hrs)

Introduction to EHV Transmission Comparison of AC and DC Transmission Systems. Parameters of EHV Lines:- Resistance of conductors, bundle conductors, Inductance of EHV Line configurations line capacitance, Sequence Inductance and capacitance, Line parameters for modes of propagation, resistance and Inductance of Ground returns.

Module- II (10 hrs)

Voltage Gradient of conductors:- Field of sphere gap, field of line charges and their properties. Charge – potential relations for multi-conductor lines surface voltage gradient and conductors without and with ground wires consideration, gradient factors, Distribution of voltage gradient on sub-conductors of bundle.

Module- III (10 hrs)

Corona effects- I : Power loss and Audible Noise Corona loss, Charge- Voltage diagram. Attenuation of traveling waves. **Audible Noise:** Generation, Characteristics and its limitation, Measurement, meters, 1-phase and 3-phase AN levels, Day-Night equivalent Noise level.
Power frequency voltage control and over-voltage:- Generalised constants, Cascade connection of components-shunt and series compensation. Sub-synchronous Resonance in series- capacitor compensated lines, Static Reactive compensating systems.

Module – IV (10 hrs)

Over voltage in EHV systems caused by switching operations:-
Origin of over voltage and their types, short circuit current and circuit breaker. Recovery voltage and the circuit breaker, Over voltage caused by interruption of inductive current, Interruption of capacitive currents, Ferro resonance over voltage, calculation of switching surges single phase equivalents, distributed parameter line energized by source, generalized equations for single phase representation, Generalised equation of three phase systems, inverse Fourier transform for the general case, Reduction of switching surges on EHV systems, Experimental and calculated results of switching surge studies.

Books:-

1. Begamudre R.D., "Extra High Voltage A.C. Transmission" McGraw Hill 1968.

OPERATION & CONTROL OF ELECTRICAL ENERGY SYSTEMS

MODULE-I:

Real Time Monitoring of Power Systems : State Estimation, Topological observability Analysis, Security Analysis of Power Systems, Economic Dispatch & Unit Commitment

MODULE-II:

Control of Power & Frequency : Turbine -Governor Control Loops, Single Area and Multi-Area Systems Control, Effect of high penetration of Wind & Other Renewable/Distributed Generation on P-F Control.

MODULE-III:

Control of Voltage & Reactive Power: Generator Excitation Systems, & Automatic Voltage Regulators, Transformer Tap Changes Controls, Voltage Control in Distribution Networks using New Power Electronic Devices.

MODULE-IV:

Introduction to Market operations in Electric Power Systems : Restructured Power Systems, Short Term Load Forecasting, Power Trading through Bilateral, Multilateral Contracts and Power Exchanges, Role of Distributed Generators in market Operations.

TEXT BOOKS

1. Wood, A.J. and B.F. Wollenberg, Power Generation Operation and Control, Wiley – Interscience Publication, Second Ediction (2003).
2. O.I. Elgard, Electric Energy Systems Theory : An Introductuion, Tata McGraw Hill Publication, Second Edition, 1982
3. Shahidepour, M. et al, Market Operationhs in Electric Power Systems, Wiley Interscience & IEEE Publication, 2002.
4. Bhattacharya et al, Operation of Restructured Power Systems, Kluwer Academic Publishers, 2001.

POWER SYSTEM RELIABILITY

Module-I (10Hours)

Generating Capacity Basic Probability Methods: The generation system model, Loss of load indices, Equivalent forced outage rate, Capacity expansion analysis, Scheduled outages, Evaluation methods on period basis, Load forecast uncertainty, Forced outage rate uncertainty, Loss of energy indices.

Generating Capacity Frequency & Duration Method*:* The generation model, System risk indices.

Module-II (12 Hours)

Interconnected Systems: Probability error method in two interconnected systems, Equivalent assisting unit approach to two interconnected systems, Factors affecting the emergency assistance available through the interconnections, Variable reserve versus maximum peak load reserve, Reliability evaluation in three interconnected system, multi connected system, Frequency & duration approach.

Operating Reserve: General concepts, PJM method, Extension to PJM method, Modified PJM method, Postponable outages, Security function approach, Response risk, Interconnected systems.

Module-III (10 Hours)

Composite Generation & Transmission Systems: Radial configurations, Conditional probability approach, Network configurations, State selection, System & load point indices, Application to practical systems, Data requirements for composite system reliability.

Plant & Station Availability: Generating plant availability, Derated states & auxiliary systems, Allocation & effect of spares, Protection systems, HVDC systems.

Module-IV (11 Hours)

Distribution Systems Basic Techniques & Radial Networks: Evaluation techniques, additional interruption indices, Application to radial systems, effect of lateral distributor protection, Effect of disconnects, Effect of protection failures, effect of transferring loads, Probability distributions of reliability indices.

Distribution Systems-Parallel & Meshed Networks: Basic evaluation techniques, Inclusion of busbar failures, Inclusion of scheduled maintenance, Temporary & transient failures, Inclusion of weather effects, Common modes failures, Common mode failures & weather effects, Inclusion of breaker failures.

Text Books

1. Billinton Roy& Allan Ronald “Reliability of Power system”, Pitman Pub. 1984
2. Richard Elect. Brown, “Electric Power Distribution Reliabilty”, CRC Press

ADVANCED CONTROL SYSTEMS

Module-I : (10 Hours)

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

Module -II : (12 Hours)

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

Module - III : (11 Hours)

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

Module - IV : (10 Hours)

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

Text/References :

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

ENERGY GENERATION FROM WASTE

MODULE-I:

Solid Waste Sources Solid Waste Sources, types, composition, Properties, Municipal Solid Waste: Physical, chemical and biological properties , Waste Collection and, Transfer stations, Waste minimization and recycling of municipal waste, Segregation of waste, Size Reduction , Managing Waste.

MODULE-II:

Status of technologies for generation of Energy from Waste Waste Treatment and Disposal Aerobic composting, incineration, Furnace type and design, Medical waste /Pharmaceutical waste treatment Technologies, incineration, Environmental impacts, Measures to mitigate environmental effects due to incineration.

MODULE-III:

Land Fill method of Solid waste disposal Land fill classification, Types, methods and Sitting consideration, Layout and preliminary design of landfills: Composition, characteristics, generation, Movement and control of landfill leachate and gases, Environmental monitoring system for land fill gases.

MODULE-IV:

Energy Generation from Waste Bio-chemical Conversion: Sources of energy generation, Anaerobic digestion of sewage and municipal wastes, Direct combustion of MSW-refuse derived solid fuel, Industrial waste, agro residues, Anaerobic Digestion: Biogas production, Land fill gas generation and utilization, Thermo-chemical conversion: Sources of energy generation, Gasification of waste using Gasifiers , Briquetting, Utilization and advantages of briquetting, Environmental benefits of Bio-chemical and Thermo- chemical conversion .

Text Books/References:

1. Nicholas P. Cheremisinoff. Handbook of Solid Waste Management and Waste Minimization Technologies.An Imprint of Elsevier, New Delhi (2003).
2. P. AarneVesilind, William A. Worrell and Debra R. Reinhart.Solid Waste Engineering. Thomson Asia Pte Ltd. Singapore (2002)
3. M. Dutta , B. P. Parida, B. K. Guha and T. R. Surkrishnan. Industrial Solid Waste Management and Landfilling practice. Narosa Publishing House, New Delhi (1999).
4. AmalenduBagchi. Design, construction and Monitoring of Landfills.John Wiley and Sons. New York. (1994)
5. M. L. Davis and D. A. Cornwell.Introduction to environmental engineering.McGraw Hill International Edition, Singapore (2008)
6. C. S. Rao. Environmental Pollution Control Engineering.Wiley Eastern Ltd. New Delhi (1995)
7. S. K. Agarwal. Industrial Environment Assessment and Strategy. APH Publishing Corporation. New Delhi (!996)
8. Sofer, Samir S. (ed.), Zaborsky, R. (ed.), “Biomass Conversion Processes for Energy and Fuels”, New York, Plenum Press, 1981
9. Hagerty, D.Joseph; Pavoni, Joseph L; Heer, John E., “Solid Waste Management”, New York, Van Nostrand, 1973

10. George Tchobanoglous, Hilary Theisen and Samuel Vigil Prsl: Tchobanoglous, George Theisen, Hillary Vigil, Samuel, "Integrated Solid Waste management: Engineering Principles and Management issues", New York, McGraw Hill, 1993
11. C Parker and T Roberts (Ed), Energy from Waste - An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985
12. KL Shah, Basics of Solid and Hazardous Waste Management Technology, Prentice Hall, 200
13. M Datta, Waste Disposal in Engineered Landfills, Narosa Publishing House, 1997
14. G Rich et.al, Hazardous Waste Management Technology, Podvan Publishers, 1987
15. AD Bhide, BB Sundaresan, Solid Waste Management in Developing Countries, INSDOC, New Delhi,1983

POWER QUALITY IMPROVEMENT TECHNIQUES

Module-I : (15 Hours)

Concept of Power Quality: Frequency variations, voltage variations- sag and swell,waveform distortion –dc offset,harmonics, inter-harmonics, notching and noise. Fundamentals of Harmonics: Representation of harmonics,waveform, harmonic power, measures of harmonic distortion;Current and voltage limits of harmonic distortions: IEEE, IEC, EN,NORSOK.
Causes of Harmonics: 2-pulse, 6-pulse and 12-pulse converter configurations, input current waveforms and their harmonic spectrum; Input supply harmonics of AC regulator, integral cycle control, cycloconverter, transformer, rotating machines, ARC furnace, TV and battery charger.

Module-II : (14 Hours)
Effect of Harmonics: Parallel and series resonance, effect of harmonics on static power plant – transmission lines, transformers,capacitor banks, rotating machines, harmonic interference withripple control systems, power system protection, consumer equipments and communication systems, power measurement.
Elimination/ Suppression of Harmonics: High power factorconverter, multi-pulse converters using transformer connections(delta, polygon).

Module-III : (15 Hours)
Passive Filters: Types of passive filters, single tuned and high passfilters, filter design criteria, double tuned filters, damped filters andtheir design.Active Power Filters: Compensation principle, classification ofactive filters by objective, system configuration, power circuit and control strategy.
PWM Inverter: Voltage sourced active filter, current sourced active filter, constant frequency control, constant tolerance bandcontrol, variable tolerance band control.

Module-IV : (15 Hours)
Shunt Active Filter: Single-phase active filter, principle of operation, expression for compensating current, concept of constant capacitor voltage control; Three-phase active filter: Operation, analysis and modelling; Instantaneous reactive power theory..Three-phase Series Active Filter: Principle of operation, analysis and modelling. Other Techniques: Unified power quality conditioner, voltagesource and current source configurations, principle of operation for sag, swell and flicker control.

Text/Reference Books:

1. Derek A. P., “Power Electronic Converter Harmonics”, IEEE Press. 1989
2. Arrillaga J., Smith B. C., Watson N. R. and Wood A. R., “PowerSystem Harmonic Analysis”, 2nd 2008Ed., Wiley India.
3. Arthur R. B., “Power System Analysis”, 2nd Ed., Pearson Education. 2008
4. Arrillaga J., Braedlley D. A. and Bodger P. S., “Power System Harmonics”, John Wiley and Sons.1985
5. Dugan R. C., McGranaghan M. F. and Beaty H. W., Electrical Power System Quality”, McGraw-Hill International Book Company.1996
6. Sankaran C., “Power Quality”, CRC Press. 2001

PROTECTION AND DEGITAL RELAYING

Module-I

Protection Schemes and Characteristics: Primary and back up protection , current transformers for protection , potential transformer, review of electromagnetic relays static relays , over current relays time current characteristic, current setting time setting, directional relay, static over current relays.

Module-II

Distance protection: impedance, reactance, mho, angle impedance relays. Input quantities for various types of distance relays, effect of arc resistance on the performance of distance relays, selection of distance relays. MHO relay with blinders, quadrilateral relay , elliptical relay. Restricted mho, impedance directional, reactance relays, swiveling characteristics.

Module-III

Compensation Schemes: Compensation for correct distance measurement , reduction of measuring units switched schemes. Pilot relaying schemes. Wire pilot protection , circulating current scheme, balanced voltage scheme, transley scheme, carrier current protection , phase comparison carrier current protection, carrier aided distance protection.

Module-IV

Digital Relaying: Digital relaying algorithms, differential equation technique, discrete Fourier transform technique, walsh-hadamard transform technique, rationalized harr transform technique, removal of dc offset.
Microprocessor based protective relays: over current , directional, impedance, reactance relays. Generalized mathematical expressions for distance relays, mho and offset mho relays, quadrilateral relay, microprocessor implementation of digital distance relaying algorithms.

Text book

1. Power system protection and switchgear by Badri ram and vishwkrama, TMH publication New Delhi 1995.

2. power system protection by Madhava Rao TMH

Reference Books

1. Power system by Ravindra Nath and chandar PHI.

ELECTRIC DRIVES IN HYBRID VEHICLE

Module-I : (11 Hours)

Introduction: History of hybrid vehicles, architectures of HEVs,series and parallel HEVs, complex HEVs. Hybridization of Automobile: Fundamentals of vehicle,components of conventional vehicle and propulsion load; Drivecycles and drive terrain; Concept of electric vehicle and hybrid electric vehicle; Plug-in hybrid vehicle, constituents of PHEV, comparison of HEV and PHEV; Fuel Cell Vehicles and itsconstituents.

Module-II : (10 Hours)

Plug in Hybrid Electric Vehicle: PHEVs and EREVs, blended PHEVs, PHEVArchitectures, equivalent electric range of blendedPHEVs; Fuel economy of PHEVs, power management of PHEVs,end-of-life battery for electric power grid support, vehicle to grid technology, PHEV battery charging.

Module-III : (10 Hours)

Power Electronics in HEVs: Rectifiers used in HEVs, voltage ripples; Buck converter used in HEVs, non-isolated bidirectional DC-DC converter, regenerative braking, voltage source inverter,current source inverter, isolated bidirectional DC-DC converter, PWM rectifier in HEVs, EV and PHEV battery chargers.

Module-IV: (11 Hours)

Electric Machines and Drives in HEVs: Induction motor drives, Field oriented control of induction machines; Permanent magnet motor drives; Switched reluctance motors; Doubly salientpermanent magnet machines.

Suggested Books:

1. Pistooa G., "Power Sources , Models, Sustanability, Infrstructure and the market", Elsevier 2008
2. Mi Chris, Masrur A., and Gao D.W., " Hybrid Electric Vehicle: Principles and Applications with Practical Perspectives"1995

GREEN ENERGY RESOURCES & TECHNOLOGY

Module-I :

Solar photovoltaics: Introduction, Solar cell characteristics, Losses in solar cells, Modeling of solar cell, Solar PV modules, Bypass diode in PV module, Design of PV module, PV module power output, I-V curve of PV module, BOS of PV module, Batteries for solar PV, Battery charge controllers, DC-DC converters, DC-AC converters, MPPT, Different algorithm for MPPT, Types of PV system, Performance analysis of solar cell, Working of solar cell power plant.

Module-II :

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

Ocean Energy: Ocean energy resources-ocean energy routes - Principles of ocean thermal energy conversion systems- ocean thermal power plants- Principles of ocean wave energy conversion and tidal energy conversion.

Module-III :

Biomass Energy: Introduction, Biomass conversion technology, Biogas, Composition of Biogas, Properties of Biogas, Biogas production reaction, Factor affecting biogas production, Biogas plant site selection, Biogas plants, Types of Biogas plants, Biogas purification, Biogas storage, Biogas dispensing, Advantages and disadvantages of Biogas, Emission from Biogas engines, Digester Filling and Biogas plant operation, Biogas digester sizing.

Module-IV :

Hybrid Power Syatems: Introduction, Need for hybrid systems, Range of hybrid systems, Types of Hybrid systems, Diesel-PV system, Wind-PV system, Micro hydel-PV system, Biomass-PV system, Electric vehicles, Hybrid electric vehicles.

Energy Conservation, Management and Economics: Impact of renewable energy on environment, Principle and strategies of energy conservation, energy management, energy audit, energy planning, Total energy system concept, Power tariff, Cost of electricity production from renewable.

Text/Reference Books:

1. S. N. Bhadra, D. Kastha, S. Banerjee, *Wind Electrical Systems*: Oxford Univ. Press, 2005.
2. S. S. Thipse, Non Conventional and Renewable Energy Sources, Narosa Publishing House, 2014.

3. S.A. Abbasi, N. Abbasi, *Renewable Energy Sources and Their Environmental Impact:* Prentice Hall of India, 2004.
4. S.P. Sukhatme - Solar Energy: Principles of thermal Collection and Storage,TMH,New Delhi
5. Duffic and Beckman - Solar Engineering of Thermal Processes, John wiley
6. Green Management and Green Technologies: Exploring the Causal Relationship by Jazmin Seijas Nogarida,2008.
7. Green Marketing and Management: A global Perspective by John F. Whaik, 2005

QUANTITATIVE METHODS FOR ENERGY MANAGEMENT & PLANNING

MODULE-I:

A review of probability concepts, Forecasting and decision making in view of multi-variant techniques, Linear programming,

MODULE-II:

Graphical solution, Simplex method, Duality and post-optimality analysis, Integer programming .

MODULE-III:

Optimal technology mix in micro and macro level energy planning exercises, Sequencing, Queuing theory, Networks, PERT and CPM,

MODULE-IV:

Decision theory, Markov analysis, Non linear programming, Decision making with uncertainty, decision making with multiple objectives, Deterministic and probabilistic dynamic programming, Regression analysis.

Text/References

1. Operations Research, An Introduction, Sixth Edition, 2000, by HA Taha, Prentice-Hall of India Pvt. Ltd.
2. Quantitative Techniques in Management, First Edition, 1997, by ND Vohra, Tata McGraw-Hill Publishing Company Ltd, New Delhi.

SYSTEM IDENTIFICATION AND ADAPTIVE CONTROL

Module-I (12 Hours)

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

Module-II (12 Hours)

Recursive Identification of Linear dynamic systems: RLS, ELS, IV, RML, Stochastic Approximation, Extended Kalman Filter, generalized prediction error framework and its application to ARMA and state models, convergence analysis, Time varying parameters. Nonlinear System Identification. ; Adaptive schemes. Adaptive control theory. Applications. Situations when constant Gain feedback is insufficient.

Module-III (12 Hours)

Robust control. ; The adaptive control problem. ; The model following problem. MRAS based on stability theory. Model following when the full state is measurable.
Direct MRAS for general linear systems. Prior knowledge in MRAS. MRAS for partially known systems. Use of robust estimation methods in MRAS. ; The basic idea. Indirect self-tuning regulators. Direct Self-tuning regulators.

Module-IV (12 Hours)

Linear Quadratic STR. Adaptive Predictive control. Prior knowledge in STR.; Linear-in-the-parameters model. Least squares estimation. Experimental conditions. Recursive estimators. Extended least squares. Robust estimation methods (dead zone, projection).Implementation issues. ; Nonlinear System Identification Techniques

Essential Readings:

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

Supplementary Reading:

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

Specialization:Power Electronics & Drives/ Power Electronics/ Power Electronics & Electrical Drives

Second Semester								
Theory					Practical			
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Advanced Power Converter	4-0	4	100	50	-	-	-
Specialization Core-2 Advanced Electric Drives	4-0	4	100	50	-	-	-
Elective I(Specialization related) 1.HVDC Transmission & FACTS 2.Electrical Machine Analysis & Control 3.Power System Transient 4.Control Techniques In Power Electronics	4-0	4	100	50	-	-	-
Elective II (Departmental related) 1.Advance Control System 2. Energy Generation From Waste 3.Power Quality Improvement Techniques 4.Power System Control & Instrumentation	4-0	4	100	50	-	-	-
Elective III(from any department) 1. Electric Drives In Hybrid Vehicle 2.Green Energy Resources & Technology 3. Quantitative methods For Energy Management & planning 4.Advanced Digital Signal Processing	4-0	4	100	50	-	-	-
Lab-2 (Specialization lab to be decided by the department)					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

ADVANCED POWER CONVERTER

Module-I (10 hours) **:**Switched Mode Rectifier - Operation of Single/Three Phase Bridges in Rectifier Mode . Control Principles .Control of the DC Side Voltage.Voltage Control Loop. The inner Current Control Loop. Special Inverter Topologies - Current Source Inverter .Ideal Single Phase CSI operation, analysis and waveforms - Analysis of Single Phase Capacitor Commutated CSI. Series Inverters . Analysis of Series Inverters . Modified Series Inverter .Three Phase Series Inverter.

Module-II (12 hours) : Multi-Level Inverters of Diode Clamped Type, Flying Capacitor Type and Cascaded type; Basic Topology and Waveforms, Improvement in harmonics, High Voltage Applications: load compensation, series compensation, suitable modulation strategies - Space Vector Modulation - Minimum ripple current PWM method. Current Regulated Inverter -Current Regulated PWM Voltage Source Inverters . Methods of Current Control . Hysteresis Control . Variable Band Hysteresis Control . Fixed Switching Frequency Current Control Methods . Switching Frequency Vs accuracy of Current Regulation . Areas of application of Current Regulated VSI .

Module-III (11 hours) Buck, Boost, Buck-Boost SMPS Topologies . Basic Operation- Waveforms - modes of operation – Output voltage ripple Push-Pull and Forward Converter Topologies - Basic Operation .Waveforms - Voltage Mode Control. Half and Full Bridge Converters . Basic Operation and Waveforms- FlybackConverter .discontinuous mode operation . waveforms . Control - Continuous Mode Operation . Waveforms Introduction to Resonant Converters .

Module-IV (13 hours):

Classification of Resonant Converters . Basic Resonant Circuit Concepts . Load Resonant Converter . Resonant Switch Converter . Zero Voltage Switching Clamped Voltage Topologies . Resonant DC Link Inverters with Zero Voltage Switching .High Frequency Link Integral Half Cycle Converter.Introduction to active power factor control.

Texts/References:

1. Ned Mohan et.al : Power Electronics,John Wiley and Sons

2. Rashid :Power Electronics, Prentice Hall India

3. G.K.Dubeyet.al :Thyristorised Power Controllers, Wiley Eastern L

ADVANCED ELECTRICAL DRIVES

Module I(10 Hours)

Principles for vector and field-oriented control-Complex-valued dq-model of induction machines. Turns ratio and modified dq-models. Principles for field-oriented vector control of ac machines. Current controllers in stationary and synchronous coordinates. Rotor-flux oriented control of current-regulated induction machine.

Module II(10 Hours)

Dynamic model of IM in rotor-flux coordinates. Indirect rotor-flux oriented control of IM - Direct rotor-flux oriented control of IM.- Methods to estimation of rotor-flux Generalized flux-vector control using current- and voltage decoupling networks. Generalized flux-vector oriented control. Current and voltage decoupling networks.Airgap-oriented control. Voltage-fed vector control. Stator-flux oriented vector control.

Module III(11 Hours) Parameter sensitivity, selection of flux level, and field weakening - Parameter detuning in steady-state operation. Parameter detuning during dynamics.Selection of flux level. Control strategies for used in the over-speed region .

Module IV(15 Hours) Principles for speed sensor-less control - Principles for speed sensor-less control. Sensor-less methods for scalar control. Sensor-less methods for vector control .Introduction to observer-based techniques . Direct torque control Induction Motor Drives. Self control synchronous motor drives. Introduction to speed control of switched reluctance machine. Control of Permanent magnet synchronous machine, Brushless dc Machine, Surface Permanent Magnet Machine and interior.

Text/References:

1. B. K. Bose, Modern Power Electronics and A.C. Drives, PHI, 2002.

2. G. K. Dubey, Power Semiconductor Controlled Drives, Prentice-Hall International, 1989.

Supplementary Reading:

1. G. K. Dubey, Fundamentals of Electrical Drives, Narosa Publishing House, 2002.

2. W. Leonhard, Control of Electrical drives, Springer-Verlag, 1985.

3. P.C. Sen,Thyristor DC Drives,Wiley-Interscience Pub., Digitized on Dec, 2006.

HVDC TRANSMISSION& FACTS

Module-I(10hours)

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

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

Module-II :(11hours)

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

Module-III:(15hours)

FACTS Concept and General System:

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

Module-IV:(15hours)

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

Text/References:

1.Padiyar K.R., “HVDC Power Transmission System”, Wiely Eastern PVT Limited

2.Kimbark, “Direct Current transmission”, Vol.1, John Wielly, New York, 1971

3.Understanding FACTS: Cocepts and Technology of Flexible AC Transmission Systems. By N. G. Hingorani and L. Gyugi, Standard Publisher Distributors, IEEE Press, Delhi

4.Flexible AC Transmission Systems. By J. Arillage 13

ELECTRICAL MACHINE ANALYSIS & CONTROL

Module-1(10 hrs)
Generalized transformations, Physical model, Different reference frame, Primitive machine, dynamic variable, Formulation of dynamic equations of a generalized machine in arbitrary reference frame

Module-2(12 hrs)
Analysis of induction machines, Space vector, induction motor modeling in arbitrary reference frame and in field oriented frame, Performance analysis.

Module-3(8 hrs)
Analysis of synchronous machine, Modeling, Operational impedances, Time constants, torque expression, Asynchronous damping,

Module-4(12 hrs)
Steady state and transient performance, Phasor diagram and power angle characteristics, Symmetrical and asymmetrical short circuit analysis, Measurement of reactances and time constants

TEXT BOOKS:

1. Herbert Schildt: Java The Complete Reference, 7th Edition, Tata McGraw Hill, 2007.
2. Robert W. Sebesta: Programming the World Wide Web, 4th Edition, Pearson Education, 2008.

Text/References:

- Concordia, Charles, “Synchronous Machines- Theory and Performance”, Wiley, New York. 1989
- Kimbark E.W., Power System Stability: Synchronous Machines”, Vol.3, Cover Publication, New York. 1976
- Adkins B., Harley R.G., “The Generalized Theory of Alternating Current Machines”, Chapman & Hall, London. 1979
- Leonard W., “Control of Electrical Drives”, 3rd Edition. Springer Press, New York. 2002
- Murphy J.M.D., Turnbull F.G., “Power Electronics Control of AC Motors”, Pergamon Press, New York. 1988
- C. V. Jones, “The Unified theory of Electrical machines”.,Butterworth , London, 1967.

POWER SYSTEMS TRANSIENTS

Module-I (11 Hours)

INTRODUCTION TO FAST TRANSIENTS:

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

Module-I I(10 Hours)

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

THEORY OF GROUNDS WIRES :Direct stoke to a tower, effect of reflection up and down the tower , the counterpoise.

Module-III (10Hours)

SWITCHING SURGES :

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

High frequency oscillations and terminal transients of transformer

Module-IV (12 Hours)

INSULATION COORDINATION:

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

TEXT/REFERENCES:

1.Allan Greenwood , Electrical Transients in power Systems , Wiley Iterscience, 1991

2.Lou Van Der Sluis, Transients in power Systems , John Wiley & Sons Ltd, 2001

3.RRudenterg, Transient Performance of Electric power systems, Phenomenon in Lumped Networks, MGH, 1950

4.RRudenterg, Electric Stroke waves in power systems, Harvard University press, Cambridge, Massachusetts, 1968

5.Transmission Line Reference Book, EPRI, USA, 1982 11

CONTROL TECHNIQUES IN POWER ELECTRONICS

Module-1

Voltage and current commutated choppers, buck converter, boost converter, Cuk converter. Three-phase ac regulators, Single-phase and three-phase Cyclo-converters, Line commutated and forced commutated inverters, three phase voltage source inverters, voltage and frequency control. PWM converters: Single-pulse and multiple pulse modulation techniques. Multi-pulse converters using delta/ zigzag/ Fork /Polygon transformers, analysis and harmonic calculations..

Module-2

High quality single-phase and three-phase converters control techniques, Buck, Boost control, Power, flow control, hysteresis and carrier wave control, space vector control. Multi-level converters control techniques. Conventional methods of power factor improvement techniques, controlled free-wheeling operation, asymmetrical triggering, sequence control of phase controlled converters, extinction angle control;

Module-3

State space modeling and simulation of linear systems, Discrete time models, Conventional controller using small signal models, Fuzzy control,Hysteresis Controllers, Output and state feedback switching controller.Sliding mode control. Direct and indirect control of buck, cuk, boost Converters.

Module-4

Digital Control Circuits for Power Electronics Systems . Analog Versus Digital Control Circuit. Causal and Noncausal Circuits.LTI Discrete-Time Circuits.Digital Filters.Hard Real-Time Control Systems.Multirate Control Circuits.

Text/References:

- Mohan N., Undeland T. M. and Robbins W. P., “Power Electronics- Converters, Applications and Design”, 3rd 2008 Ed., Wiley India.
- Murphy J.M.D., Turnbull F.G., “Power Electronics Control of AC Motors”, Pergamon Press, New York.
- Kazmierkpwski M. P., Krishnan R. and Blaabjerg F., “Control in Power Electronics – Selected Problems”, Academic Press.
- Krzysztof Sozanski,“Digital Signal Processing in Power Electronics Control Circuits”., Springer, London.
- H. S. Ramírez and R. S.-Ortigoza,“Control Design Techniques in Power Electronics Devices”. Springer, London.

ADVANCED CONTROL SYSTEMS

Module-I : (10 Hours)

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

Module -II : (12 Hours)

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

Module - III : (11 Hours)

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

Module - IV : (10 Hours)

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

Text/References:

1. Discrete Time Control Systems, by K.Ogata, 2nd edition (2001), Pearson Education publication.
2. Digital Control Systems, by B.C. Kuo, 2nd edition (1992), Oxford University Press.
3. Digital Control and State Variable Methods, by M.Gopal, 3rd edition (2009), Tata Mc. Graw Hill Education Pvt. Ltd.
4. Systems and Control by Stanislaw H.Zak, Oxford University Press (2003).
5. Design of Feedback Control Systems by Raymond T. Stefani, B.Shalia, Clement J. Savant, Jr. Gen H. Hostetter, 4th edition (2002), Oxford University Press.
6. Introduction to Control Engineering (Modeling, Analysis and Design) by Ajit K. Mandal, New Age International (P), Ltd., Publishers (2006).
7. Non Linear Systems, by Hassan K. Khallil, 3rd edition (2002), Prentice Hall, Inc. (Pearson Education), Publications.
8. Control Theory (Multivariable and non linear Methods) by Torkel Glad &LennartLjung, Taylor & Francis (2009). 16

ENERGY GENERATION FROM WASTE

MODULE-I:

Solid Waste Sources Solid Waste Sources, types, composition, Properties, Municipal Solid Waste: Physical, chemical and biological properties , Waste Collection and, Transfer stations, Waste minimization and recycling of municipal waste, Segregation of waste, Size Reduction , Managing Waste.

MODULE-II:

Status of technologies for generation of Energy from Waste Waste Treatment and Disposal Aerobic composting, incineration, Furnace type and design, Medical waste /Pharmaceutical waste treatment Technologies, incineration, Environmental impacts, Measures to mitigate environmental effects due to incineration.

MODULE-III:

Land Fill method of Solid waste disposal Land fill classification, Types, methods and Sitting consideration, Layout and preliminary design of landfills: Composition, characteristics, generation, Movement and control of landfill leachate and gases, Environmental monitoring system for land fill gases.

MODULE-IV:

Energy Generation from Waste Bio-chemical Conversion: Sources of energy generation, Anaerobic digestion of sewage and municipal wastes, Direct combustion of MSW-refuse derived solid fuel, Industrial waste, agro residues, Anaerobic Digestion: Biogas production, Land fill gas generation and utilization, Thermo-chemical conversion: Sources of energy generation, Gasification of waste using Gasifiers , Briquetting, Utilization and advantages of briquetting, Environmental benefits of Bio-chemical and Thermo- chemical conversion .

Text Books/References:

1. Nicholas P. Cheremisinoff. Handbook of Solid Waste Management and Waste Minimization Technologies.An Imprint of Elsevier, New Delhi (2003).
2. P. AarneVesilind, William A. Worrell and Debra R. Reinhart.Solid Waste Engineering. Thomson Asia Pte Ltd. Singapore (2002)
3. M. Dutta , B. P. Parida, B. K. Guha and T. R. Surkrishnan. Industrial Solid Waste Management and Landfilling practice. Narosa Publishing House, New Delhi (1999).
4. AmalenduBagchi. Design, construction and Monitoring of Landfills.John Wiley and Sons. New York. (1994)
5. M. L. Davis and D. A. Cornwell.Introduction to environmental engineering.McGraw Hill International Edition, Singapore (2008)
6. C. S. Rao. Environmental Pollution Control Engineering.Wiley Eastern Ltd. New Delhi (1995)
7. S. K. Agarwal. Industrial Environment Assessment and Strategy. APH Publishing Corporation. New Delhi (!996)
8. Sofer, Samir S. (ed.), Zaborsky, R. (ed.), “Biomass Conversion Processes for Energy and Fuels”, New York, Plenum Press, 1981
9. Hagerty, D.Joseph; Pavoni, Joseph L; Heer, John E., “Solid Waste Management”, New York, Van Nostrand, 1973

10. George Tchobanoglous, Hilary Theisen and Samuel Vigil Prsl: Tchobanoglous, George Theisen, Hillary Vigil, Samuel, “Integrated Solid Waste management: Engineering Principles and Management issues”, New York, McGraw Hill, 1993
11. C Parker and T Roberts (Ed), Energy from Waste - An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985
12. KL Shah, Basics of Solid and Hazardous Waste Management Technology, Prentice Hall, 2000
13. M Datta, Waste Disposal in Engineered Landfills, Narosa Publishing House, 1997
14. G Rich et.al, Hazardous Waste Management Technology, Podvan Publishers, 1987
15. AD Bhide, BB Sundaresan, Solid Waste Management in Developing Countries, INSDOC, New Delhi,1983

POWER QUALITY IMPROVEMENT TECHNIQUES

Module-I : (15 Hours)
Concept of Power Quality: Frequency variations, voltage variations- sag and swell,waveform distortion –dc offset,harmonics, inter-harmonics, notching and noise. Fundamentals of Harmonics: Representation of harmonics,waveform, harmonic power, measures of harmonic distortion;Current and voltage limits of harmonic distortions: IEEE, IEC, EN,NORSOK.
Causes of Harmonics: 2-pulse, 6-pulse and 12-pulse converter configurations, input current waveforms and their harmonic spectrum; Input supply harmonics of AC regulator, integral cycle control, cycloconverter, transformer, rotating machines, ARC furnace, TV and battery charger.
Module-II : (14 Hours)
Effect of Harmonics: Parallel and series resonance, effect of harmonics on static power plant – transmission lines, transformers,capacitor banks, rotating machines, harmonic interference withripple control systems, power system protection, consumer equipments and communication systems, power measurement. Elimination/ Suppression of Harmonics: High power factorconverter, multi-pulse converters using transformer connections(delta, polygon).
Passive Filters: Types of passive filters, single tuned and high passfilters, filter design criteria, double tuned filters, damped filters andtheir design.Active Power Filters: Compensation principle, classification ofactive filters by objective, system configuration, power circuit and control strategy.
Module-III : (15 Hours)
PWM Inverter: Voltage sourced active filter, current sourced active filter, constant frequency control, constant tolerance bandcontrol, variable tolerance band control. Shunt Active Filter: Single-phase active filter, principle of operation, expression for compensating current, concept of constant capacitor voltage control; Three-phase active filter: Operation, analysis and modelling; Instantaneous reactive power theory..Three-phase Series Active Filter: Principle of operation, analysis and modelling. Other Techniques: Unified power quality conditioner, voltagesource and current source configurations, principle of operation for sag, swell and flicker control.

Text/References:
1. Derek A. P., “Power Electronic Converter Harmonics”, IEEE Press. 1989
2. Arrillaga J., Smith B. C., Watson N. R. and Wood A. R., “PowerSystem Harmonic Analysis”, 2nd2008Ed., Wiley India.
3. Arthur R. B., “Power System Analysis”, 2nd Ed., Pearson Education. 2008
4. Arrillaga J., Braedlley D. A. and Bodger P. S., “Power System Harmonics”, John Wiley and Sons.1985
5. Dugan R. C., McGranaghan M. F. and Beaty H. W., Electrical Power System Quality”, McGraw-Hill International Book Company.1996
6. Sankaran C., “Power Quality”, CRC Press. 2001

POWER SYSTEM CONTROL AND INSTRUMENTATION

Module-1

Control of voltage, frequency and tie-line power flows, Q-V and P-f control loops. Mechanism of real and reactive power control.

Module-2

Net interchange tie line bias control.Optimal, sub-optimal and decentralised controllers.AGC in isolated and interconnected power systems, AGC with economic dispatch.Discrete mode AGC.

Module-3

Time error and inadvetent interchange correction techniques. On line computer control.Distributed digital control.Data acquisition systems.Emergency control, Preventive control, system wide optimization.

Module-4

SCADA.supervisory control, supervisory master stations, remote terminal units, communication links, SCADA systems applications in power networks. System measurements using SCADA and computer Control.

Text Books /References:

- Wood A. J. and Wollenberg B.F., " Power Generation, Operation and Control, John Wiley & Sons
- Kundur P. and Balu N. J., "Power System Stability and Control", EPRI Series, McGraw-Hill International Book Company.
- "Modern Power Station Practice, Volume F: Control and Instrumentation", British Electricity International, Peragmon Press.
- Cegrell T., "Power System Control Technology", Prentice Hall International Edition.
- Grainger J. J. and Stevenson W. D., "Power System Analysis", Tata McGraw-Hill Publishing Company Limited.
- Anderson P. M. and Fouad A. A., "Power system control and stability", IEEE Press.
- Ronald L. Krutz"Securing SCADA system"johnwilly publication.
- Fabiosaccomanno"Electric Power System Analysis and Control"IEEE Press
- AtifS. Debs,"Modern power systems control and operation",Kluwer academic publishers

ELECTRIC DRIVES IN HYBRID VEHICLE

Module-I : (11 Hours)

Introduction: History of hybrid vehicles, architectures of HEVs,series and parallel HEVs, complex HEVs. Hybridization of Automobile: Fundamentals of vehicle,components of conventional vehicle and propulsion load; Drivecycles and drive terrain; Concept of electric vehicle and hybrid electric vehicle; Plug-in hybrid vehicle, constituents of PHEV, comparison of HEV and PHEV; Fuel Cell Vehicles and itsconstituents.

Module-II : (10 Hours)

Plug-in Hybrid Electric Vehicle: PHEVs and EREVs, blended PHEVs,PHEVArchitectures,equivalent electric range of blendedPHEVs; Fuel economy of PHEVs, power management of PHEVs,end-of-life battery for electric power grid support, vehicle to grid technology, PHEV battery charging.

Module-III : (10 Hours)

Power Electronics in HEVs: Rectifiers used in HEVs, voltage ripples; Buck converter used in HEVs, non-isolated bidirectional DC-DC converter, regenerative braking, voltage source inverter,current source inverter, isolated bidirectional DC-DC converter, PWM rectifier in HEVs, EV and PHEV battery chargers.

Module-IV: (11 Hours)

Electric Machines and Drives in HEVs: Induction motor drives, Field oriented control of induction machines; Permanent magnet motor drives; Switched reluctance motors; Doubly salientpermanent magnet machines.

Text Books/References:

1. Pistooa G., “Power Sources , Models, Sustanability, Infrstructure and the market”, Elsevier 2008
2. Mi Chris, Masrur A., and Gao D.W., “ Hybrid Electric Vehicle: Principles and Applications with Practical Perspectives”1995

GREEN ENERGY RESOURCES & TECHNOLOGY

Module-I :

Solar photovoltaics: Introduction, Solar cell characteristics, Losses in solar cells, Modeling of solar cell, Solar PV modules, Bypass diode in PV module, Design of PV module, PV module power output, I-V curve of PV module, BOS of PV module, Batteries for solar PV, Battery charge controllers, DC-DC converters, DC-AC converters, MPPT, Different algorithm for MPPT, Types of PV system, Performance analysis of solar cell, Working of solar cell power plant.

Module-II :

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

Ocean Energy: Ocean energy resources-ocean energy routes - Principles of ocean thermal energy conversion systems- ocean thermal power plants- Principles of ocean wave energy conversion and tidal energy conversion.

Module-III **:**

Biomass Energy: Introduction, Biomass conversion technology, Biogas, Composition of Biogas, Properties of Biogas, Biogas production reaction, Factor affecting biogas production, Biogas plant site selection, Biogas plants, Types of Biogas plants, Biogas purification, Biogas storage, Biogas dispensing, Advantages and disadvantages of Biogas, Emission from Biogas engines, Digester Filling and Biogas plant operation, Biogas digester sizing.

Module-IV :

Hybrid Power Syatems: Introduction, Need for hybrid systems, Range of hybrid systems, Types of Hybrid systems, Diesel-PV system, Wind-PV system, Micro hydel-PV system, Biomass-PV system, Electric vehicles, Hybrid electric vehicles.

Energy Conservation, Management and Economics: Impact of renewable energy on environment, Principle and strategies of energy conservation, energy management, energy audit, energy planning, Total energy system concept, Power tariff, Cost of electricity production from renewable.

Text/Reference Books:

1. S. N. Bhadra, D. Kastha, S. Banerjee, *Wind Electrical Systems*: Oxford Univ. Press, 2005.
2. S. S. Thipse, Non Conventional and Renewable Energy Sources, Narosa Publishing House, 2014.
3. S.A. Abbasi, N. Abbasi, *Renewable Energy Sources and Their Environmental Impact:* Prentice Hall of India, 2004.

4. S.P. Sukhatme - Solar Energy: Principles of thermal Collection and Storage,TMH,New Delhi
5. Duffic and Beckman - Solar Engineering of Thermal Processes, John wiley
6. Green Management and Green Technologies: Exploring the Causal Relationship by Jazmin Seijas Nogarida,2008.
7. Green Marketing and Management: A global Perspective by John F. Whaik, 2005

QUANTITATIVE METHODS FOR ENERGY MANAGEMENT & PLANNING

MODULE-I:

A review of probability concepts, Forecasting and decision making in view of multi-variant techniques, Linear programming, Graphical solution, Simplex method, Duality and post-optimality analysis, Integer programming .

MODULE-II:

Optimal technology mix in micro and macro level energy planning exercises, Sequencing, Queuing theory, Networks, PERT and CPM,

MODULE-III:

Decision theory, Markov analysis, Non linear programming, Decision making with uncertainty, decision making with multiple objectives, Deterministic and probabilistic dynamic programming, Regression analysis.

Text/References

1. Operations Research, An Introduction, Sixth Edition, 2000, by HA Taha, Prentice-Hall of India Pvt. Ltd.

2. Quantitative Techniques in Management, First Edition, 1997, by ND Vohra, Tata McGraw-Hill Publishing Company Ltd, New Delhi.

ADVANCED DIGITAL SIGNAL PROCESSING

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

Module II: (15 hours) Digital filter design and realization structures Design of IIR digital filters from analog filters- Impulse invariance method and Bilinear transformation method- FIR filter design using window functions- Comparison of IIR and FIR digital filters- Basic IIR and FIR filter realization structures- Signal flow graph representations.

Module III (10 hours) Analysis of finite word-length effects Quantization process and errors-Coefficient quantisation effects in IIR and FIR filters A/D conversion noise- Arithmetic round-off errors- Dynamic range scaling- Overflow oscillations and zero input limit cycles in IIR filters.

Module IV (11 hours) Statistical signal processing. Linear Signal Models . All pole, All zero and Pole-zero models .Power spectrum estimation- Spectral analysis of deterministic signals . Estimation of power spectrum of stationary random signals-Optimum linear filters-Optimum signal estimation-Mean square error estimation-Optimum FIR and IIR filters.

Text/ References

1. Sanjit K Mitra, Digital Signal Processing: A computer-based approach ,TataMc Grow-Hill edition .1998

2. Dimitris G .Manolakis, Vinay K. Ingle and Stephen M. Kogon, Statistical and Adaptive Signal Processing, Mc Grow Hill international editions .-2000

3. Alan V . Oppenheim, Ronald W. Schafer, Discrete-Time Signal Processing, Prentice-Hall of India Pvt. Ltd., New Delhi, 1997

4. John G. Proakis, and Dimitris G. Manolakis, Digital Signal Processing(third edition), Prentice-Hall of India Pvt. Ltd, New Delhi, 1997

5. Emmanuel C. Ifeachor, Barrie W. Jervis , Digital Signal Processing-A practical Approach, Addison . Wesley,1993

6. Abraham Peled & Bede Liu, Digital Signal Processing,John Wiley & Sons, 1976

LAB-2

(To Be Decided By The Dept.)

BRANCH-ELECTRICAL ENGINEERING

Specialization:Power Electronics & Power System

Second Semester							
Theory					Practical		
Course Name	**Hours/ Week L/T**	**Credit Theory**	**University Marks**	**Internal Evaluation**	**Hours/ Week L/T**	**Credit Practical**	**Marks**
Specialization Core-1 Advanced Power Converter	4-0	4	100	50	-	-	-
Specialization Core-2 Power System Dynamics	4-0	4	100	50	-	-	-
Elective I(Specialization related) 1.HVDC Transmission & FACTS 2.Electrical Machine Analysis & Control 3.Power System Transient 4.Control Techniques In Power Electronics	4-0	4	100	50	-	-	-
Elective II (Departmental related) 1.Advance Control System 2. Energy Generation From Waste 3.Power Quality Improvement Techniques 4.Power System Control & Instrumentation	4-0	4	100	50	-	-	-
Elective III(from any department) 1. Electric Drives In Hybrid Vehicle 2.Green Energy Resources & Technology 3. Quantitative methods For Energy Management & planning 4.Advance Microprocessor & Microcontroller	4-0	4	100	50	-	-	-
Lab-2 (Specialization lab to be decided by the department)					4	4	150
Seminar/Project					4	4	150
Total							
Total Marks: 1050							
Total Credits: 28							

ADVANCED POWER CONVERTER

Module-I (10 hours) : Switched Mode Rectifier - Operation of Single/Three Phase Bridges in Rectifier Mode . Control Principles .Control of the DC Side Voltage.Voltage Control Loop. The inner Current Control Loop. Special Inverter Topologies - Current Source Inverter .Ideal Single Phase CSI operation, analysis and waveforms - Analysis of Single Phase Capacitor Commutated CSI. Series Inverters . Analysis of Series Inverters . Modified Series Inverter .Three Phase Series Inverter.

Module-II (12 hours) : Multi-Level Inverters of Diode Clamped Type, Flying Capacitor Type and Cascaded type; Basic Topology and Waveforms, Improvement in harmonics, High Voltage Applications: load compensation, series compensation, suitable modulation strategies - Space Vector Modulation - Minimum ripple current PWM method. Current Regulated Inverter -Current Regulated PWM Voltage Source Inverters . Methods of Current Control . Hysteresis Control . Variable Band Hysteresis Control . Fixed Switching Frequency Current Control Methods . Switching Frequency Vs accuracy of Current Regulation . Areas of application of Current Regulated VSI .

Module-III (11 hours) Buck, Boost, Buck-Boost SMPS Topologies . Basic Operation- Waveforms - modes of operation – Output voltage ripple Push-Pull and Forward Converter Topologies - Basic Operation .Waveforms - Voltage Mode Control. Half and Full Bridge Converters . Basic Operation and Waveforms- FlybackConverter .discontinuous mode operation .waveforms . Control - Continuous Mode Operation . Waveforms Introduction to Resonant Converters .

Module-IV (13 hours):

Classification of Resonant Converters . Basic Resonant Circuit Concepts . Load Resonant Converter . Resonant Switch Converter . Zero Voltage Switching Clamped Voltage Topologies . Resonant DC Link Inverters with Zero Voltage Switching .High Frequency Link Integral Half Cycle Converter.Introduction to active power factor control.

Text/References:

1. Ned Mohan et.al : Power Electronics,John Wiley and Sons

2. Rashid :Power Electronics, Prentice Hall India

3. G.K.Dubeyet.al :Thyristorised Power Controllers, Wiley Eastern L

POWER SYSTEM DYNAMICS

Module-I (15 Hours)

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

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

Module-II (15 Hours)

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

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

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

Module-III (15 Hours)

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

Voltage stability, System oscillations

References:

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

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

HVDC TRANSMISSION& FACTS

Module-I(10hours)

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

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

Module-II :(11hours)

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

Module-III:(15hours)

FACTS Concept and General System:

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

Module-IV:(15hours)

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

Text/References:

1.Padiyar K.R., “HVDC Power Transmission System”, Wiely Eastern PVT Limited

2.Kimbark, “Direct Current transmission”, Vol.1, John Wielly, New York, 1971

3.Understanding FACTS: Cocepts and Technology of Flexible AC Transmission Systems. By N. G. Hingorani and L. Gyugi, Standard Publisher Distributors, IEEE Press, Delhi

4.Flexible AC Transmission Systems. By J. Arillage 13

ELECTRICAL MACHINE ANALYSIS& CONTROL

Module-1(10 hrs)

Generalized transformations, Physical model, Different reference frame, Primitive machine, dynamic variable, Formulation of dynamic equations of a generalized machine in arbitrary reference frame

Module-2(12 hrs)

Analysis of induction machines, Space vector, induction motor modeling in arbitrary reference frame and in field oriented frame, Performance analysis.

Module-3(8 hrs)

Analysis of synchronous machine, Modeling, Operational impedances, Time constants, torque expression, Asynchronous damping,

Module-4(12 hrs)

Steady state and transient performance, Phasor diagram and power angle characteristics, Symmetrical and asymmetrical short circuit analysis, Measurement of reactances and time constants

Text Books:

- Concordia, Charles, “Synchronous Machines- Theory and Performance”, Wiley, New York. 1989
- Kimbark E.W., Power System Stability: Synchronous Machines”, Vol.3, Cover Publication, New York. 1976
- Adkins B., Harley R.G., “The Generalized Theory of Alternating Current Machines”, Chapman & Hall, London. 1979
- Leonard W., “Control of Electrical Drives”, 3rd Edition. Springer Press, New York. 2002
- Murphy J.M.D., Turnbull F.G., “Power Electronics Control of AC Motors”, Pergamon Press, New York. 1988
- C. V. Jones, “The Unified theory of Electrical machines”.,Butterworth , London, 1967.

POWER SYSTEMS TRANSIENTS

Module-I (11 Hours)

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

Module-I (10 Hours)

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

THEORY OF GROUNDS WIRES :Direct stoke to a tower, effect of reflection up and down the tower , the counterpoise.

Module-III (10Hours)

SWITCHING SURGES :

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

High frequency oscillations and terminal transients of transformer

Module-IV (12 Hours)

INSULATION COORDINATION:

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

TEXT BOOKS:

1.Allan Greenwood , Electrical Transients in power Systems , Wiley Iterscience, 1991
2.Lou Van Der Sluis, Transients in power Systems , John Wiley & Sons Ltd, 2001
3.RRudenterg, Transient Performance of Electric power systems, Phenomenon in Lumped Networks, MGH, 1950
4.RRudenterg, Electric Stroke waves in power systems, Harvard University press, Cambridge, Massachusetts, 1968
5.Transmission Line Reference Book, EPRI, USA, 1982 11

CONTROL TECHNIQUES IN POWER ELECTRONICS

Module-1

Voltage and current commutated choppers, buck converter, boost converter, Cuk converter. Three-phase ac regulators, Single-phase and three-phase Cyclo-converters, Line commutated and forced commutated inverters, three phase voltage source inverters, voltage and frequency control. PWM converters: Single-pulse and multiple pulse modulation techniques. Multi-pulse converters using delta/ zigzag/ Fork /Polygon transformers, analysis and harmonic calculations..

Module-2

High quality single-phase and three-phase converters control techniques, Buck, Boost control, Power, flow control, hysteresis and carrier wave control, space vector control. Multi-level converters control techniques. Conventional methods of power factor improvement techniques, controlled free-wheeling operation, asymmetrical triggering, sequence control of phase controlled converters, extinction angle control;

Module-3

State space modeling and simulation of linear systems, Discrete time models, Conventional controller using small signal models, Fuzzy control,Hysteresis Controllers, Output and state feedback switching controller.Sliding mode control. Direct and indirect control of buck, cuk, boost Converters.

Module-4

Digital Control Circuits for Power Electronics Systems . Analog Versus Digital Control Circuit. Causal and NoncausalCircuits.LTI Discrete-Time Circuits.DigitalFilters.Hard Real-Time Control Systems.Multirate Control Circuits.

Tex Books/References:

- Mohan N., Undeland T. M. and Robbins W. P., "Power Electronics- Converters, Applications and Design", 3rd 2008 Ed., Wiley India.
- Murphy J.M.D., Turnbull F.G., "Power Electronics Control of AC Motors", Pergamon Press, New York.
- Kazmierkpwski M. P., Krishnan R. and Blaabjerg F., "Control in Power Electronics – Selected Problems", Academic Press.
- Krzysztof Sozanski,"Digital Signal Processing in Power Electronics Control Circuits"., Springer, London.
- H. S. Ramírez and R. S.-Ortigoza,"Control Design Techniques in Power Electronics Devices". Springer, London.

ADVANCED CONTROL SYSTEMS

Module-I : (10 Hours)

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

Module -II : (12 Hours)

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

Module - III : (11 Hours)

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

Module - IV : (10 Hours)

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

Text/References:

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

ENERGY GENERATION FROM WASTE

MODULE-I:

Solid Waste Sources Solid Waste Sources, types, composition, Properties, Municipal Solid Waste: Physical, chemical and biological properties , Waste Collection and, Transfer stations, Waste minimization and recycling of municipal waste, Segregation of waste, Size Reduction , Managing Waste.

MODULE-II:

Status of technologies for generation of Energy from Waste Waste Treatment and Disposal Aerobic composting, incineration, Furnace type and design, Medical waste /Pharmaceutical waste treatment Technologies, incineration, Environmental impacts, Measures to mitigate environmental effects due to incineration.

MODULE-III:

Land Fill method of Solid waste disposal Land fill classification, Types, methods and Sitting consideration, Layout and preliminary design of landfills: Composition, characteristics, generation, Movement and control of landfill leachate and gases, Environmental monitoring system for land fill gases.

MODULE-IV:

Energy Generation from Waste Bio-chemical Conversion: Sources of energy generation, Anaerobic digestion of sewage and municipal wastes, Direct combustion of MSW-refuse derived solid fuel, Industrial waste, agro residues, Anaerobic Digestion: Biogas production, Land fill gas generation and utilization, Thermo-chemical conversion: Sources of energy generation, Gasification of waste using Gasifiers , Briquetting, Utilization and advantages of briquetting, Environmental benefits of Bio-chemical and Thermo- chemical conversion .

Text Books/References:

1. Nicholas P. Cheremisinoff. Handbook of Solid Waste Management and Waste Minimization Technologies.An Imprint of Elsevier, New Delhi (2003).
2. P. AarneVesilind, William A. Worrell and Debra R. Reinhart.Solid Waste Engineering. Thomson Asia Pte Ltd. Singapore (2002)
3. M. Dutta , B. P. Parida, B. K. Guha and T. R. Surkrishnan. Industrial Solid Waste Management and Landfilling practice. Narosa Publishing House, New Delhi (1999).
4. AmalenduBagchi. Design, construction and Monitoring of Landfills.John Wiley and Sons. New York. (1994)
5. M. L. Davis and D. A. Cornwell.Introduction to environmental engineering.McGraw Hill International Edition, Singapore (2008)
6. C. S. Rao. Environmental Pollution Control Engineering.Wiley Eastern Ltd. New Delhi (1995)
7. S. K. Agarwal. Industrial Environment Assessment and Strategy. APH Publishing Corporation. New Delhi (!996)
8. Sofer, Samir S. (ed.), Zaborsky, R. (ed.), “Biomass Conversion Processes for Energy and Fuels”, New York, Plenum Press, 1981
9. Hagerty, D.Joseph; Pavoni, Joseph L; Heer, John E., “Solid Waste Management”, New York, Van Nostrand, 1973

10. George Tchobanoglous, Hilary Theisen and Samuel Vigil Prsl: Tchobanoglous, George Theisen, Hillary Vigil, Samuel, "Integrated Solid Waste management: Engineering Principles and Management issues", New York, McGraw Hill, 1993
11. C Parker and T Roberts (Ed), Energy from Waste - An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985
12. KL Shah, Basics of Solid and Hazardous Waste Management Technology, Prentice Hall, 2000
13. M Datta, Waste Disposal in Engineered Landfills, Narosa Publishing House, 1997
14. G Rich et.al, Hazardous Waste Management Technology, Podvan Publishers, 1987
15. AD Bhide, BB Sundaresan, Solid Waste Management in Developing Countries, INSDOC, New Delhi,1983

POWER QUALITY IMPROVEMENT TECHNIQUES

Module-I : (15 Hours)
Concept of Power Quality: Frequency variations, voltage variations- sag and swell,waveform distortion –dc offset,harmonics, inter-harmonics, notching and noise. Fundamentals of Harmonics: Representation of harmonics,waveform, harmonic power, measures of harmonic distortion;Current and voltage limits of harmonic distortions: IEEE, IEC, EN,NORSOK.
Causes of Harmonics: 2-pulse, 6-pulse and 12-pulse converter configurations, input current waveforms and their harmonic spectrum; Input supply harmonics of AC regulator, integral cycle control, cycloconverter, transformer, rotating machines, ARC furnace, TV and battery charger.

Module-II : (14 Hours)
Effect of Harmonics: Parallel and series resonance, effect of harmonics on static power plant – transmission lines, transformers,capacitor banks, rotating machines, harmonic interference withripple control systems, power system protection, consumer equipments and communication systems, power measurement. Elimination/ Suppression of Harmonics: High power factorconverter, multi-pulse converters using transformer connections(delta, polygon).
Passive Filters: Types of passive filters, single tuned and high passfilters, filter design criteria, double tuned filters, damped filters andtheirdesign.Active Power Filters: Compensation principle, classification ofactive filters by objective, system configuration, power circuit and control strategy.

Module-III : (15 Hours)
PWM Inverter: Voltage sourced active filter, current sourced active filter, constant frequency control, constant tolerance bandcontrol, variable tolerance band control. Shunt Active Filter: Single-phase active filter, principle of operation, expression for compensating current, concept of constant capacitor voltage control; Three-phase active filter: Operation, analysis and modelling; Instantaneous reactive power theory..Three-phase Series Active Filter: Principle of operation, analysis and modelling. Other Techniques: Unified power quality conditioner, voltagesource and current source configurations, principle of operation for sag, swell and flicker control.

Text/References:
1. Derek A. P., "Power Electronic Converter Harmonics", IEEE Press. 1989
2. Arrillaga J., Smith B. C., Watson N. R. and Wood A. R., "PowerSystem Harmonic Analysis", 2nd2008Ed., Wiley India.
3. Arthur R. B., "Power System Analysis", 2nd Ed., Pearson Education. 2008
4. Arrillaga J., Braedlley D. A. and Bodger P. S., "Power System Harmonics", John Wiley and Sons.1985
5. Dugan R. C., McGranaghan M. F. and Beaty H. W., Electrical Power System Quality", McGraw-Hill International Book Company.1996
6. Sankaran C., "Power Quality", CRC Press. 2001

POWER SYSTEM CONTROL AND INSTRUMENTATION

Module-1

Control of voltage, frequency and tie-line power flows, Q-V and P-f control loops. Mechanism of real and reactive power control.

Module-2

Net interchange tie line bias control.Optimal, sub-optimal and decentralised controllers.AGC in isolated and interconnected power systems, AGC with economic dispatch.Discrete mode AGC.

Module-3

Time error and inadvetent interchange correction techniques. On line computer control.Distributed digital control.Data acquisition systems.Emergency control, Preventive control, system wide optimization.

Module-4

SCADA.supervisory control, supervisory master stations, remote terminal units, communication links, SCADA systems applications in power networks. System measurements using SCADA and computer Control.

Text Books /References:

- Wood A. J. and Wollenberg B.F., " Power Generation, Operation and Control, John Wiley & Sons
- Kundur P. and Balu N. J., "Power System Stability and Control", EPRI Series, McGraw-Hill International Book Company.
- "Modern Power Station Practice, Volume F: Control and Instrumentation", British Electricity International, Peragmon Press.
- Cegrell T., "Power System Control Technology", Prentice Hall International Edition.
- Grainger J. J. and Stevenson W. D., "Power System Analysis", Tata McGraw-Hill Publishing Company Limited.
- Anderson P. M. and Fouad A. A., "Power system control and stability", IEEE Press.
- Ronald L. Krutz"Securing SCADA system"johnwilly publication.
- Fabiosaccomanno"Electric Power System Analysis and Control"IEEE Press
- AtifS. Debs,"Modern power systems control and operation",Kluwer academic publishers

ELECTRIC DRIVES IN HYBRID VEHICLE

Module-I : (11 Hours)

Introduction: History of hybrid vehicles, architectures of HEVs,series and parallel HEVs, complex HEVs. Hybridization of Automobile: Fundamentals of vehicle,components of conventional vehicle and propulsion load; Drivecycles and drive terrain; Concept of electric vehicle and hybrid electric vehicle; Plug-in hybrid vehicle, constituents of PHEV, comparison of HEV and PHEV; Fuel Cell Vehicles and itsconstituents.

Module-II : (10 Hours)
Plug-in Hybrid Electric Vehicle: PHEVs and EREVs, blended PHEVs,PHEVArchitectures,equivalent electric range of blendedPHEVs; Fuel economy of PHEVs, power management of PHEVs,end-of-life battery for electric power grid support, vehicle to grid technology, PHEV battery charging.

Module-III : (10 Hours)
Power Electronics in HEVs: Rectifiers used in HEVs, voltage ripples; Buck converter used in HEVs, non-isolated bidirectional DC-DC converter, regenerative braking, voltage source inverter,current source inverter, isolated bidirectional DC-DC converter, PWM rectifier in HEVs, EV and PHEV battery chargers.

Module-IV: (11 Hours)
Electric Machines and Drives in HEVs: Induction motor drives, Field oriented control of induction machines; Permanent magnet motor drives; Switched reluctance motors; Doublysalientpermanent magnet machines.

Text Books/References:

1. Pistooa G., “Power Sources , Models, Sustanability, Infrstructure and the market”, Elsevier 2008
2. Mi Chris, Masrur A., and Gao D.W., “ Hybrid Electric Vehicle: Principles and Applications with Practical Perspectives”1995

GREEN ENERGY RESOURCES & TECHNOLOGY

Module-I :

Solar photovoltaics: Introduction, Solar cell characteristics, Losses in solar cells, Modeling of solar cell, Solar PV modules, Bypass diode in PV module, Design of PV module, PV module power output, I-V curve of PV module, BOS of PV module, Batteries for solar PV, Battery charge controllers, DC-DC converters, DC-AC converters, MPPT, Different algorithm for MPPT, Types of PV system, Performance analysis of solar cell, Working of solar cell power plant.

Module-II :

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

Ocean Energy: Ocean energy resources-ocean energy routes - Principles of ocean thermal energy conversion systems- ocean thermal power plants- Principles of ocean wave energy conversion and tidal energy conversion.

Module-III **:**

Biomass Energy: Introduction, Biomass conversion technology, Biogas, Composition of Biogas, Properties of Biogas, Biogas production reaction, Factor affecting biogas production, Biogas plant site selection, Biogas plants, Types of Biogas plants, Biogas purification, Biogas storage, Biogas dispensing, Advantages and disadvantages of Biogas, Emission from Biogas engines, Digester Filling and Biogas plant operation, Biogas digester sizing.

Module-IV :

Hybrid Power Syatems: Introduction, Need for hybrid systems, Range of hybrid systems, Types of Hybrid systems, Diesel-PV system, Wind-PV system, Micro hydel-PV system, Biomass-PV system, Electric vehicles, Hybrid electric vehicles.

Energy Conservation, Management and Economics: Impact of renewable energy on environment, Principle and strategies of energy conservation, energy management, energy audit, energy planning, Total energy system concept, Power tariff, Cost of electricity production from renewable.

Text/Reference Books:

1. S. N. Bhadra, D. Kastha, S. Banerjee, *Wind Electrical Systems*: Oxford Univ. Press, 2005.
2. S. S. Thipse, Non Conventional and Renewable Energy Sources, Narosa Publishing House, 2014.
3. S.A. Abbasi, N. Abbasi, *Renewable Energy Sources and Their Environmental Impact:* Prentice Hall of India, 2004.

4. S.P. Sukhatme - Solar Energy: Principles of thermal Collection and Storage,TMH,New Delhi
5. Duffic and Beckman - Solar Engineering of Thermal Processes, John wiley
6. Green Management and Green Technologies: Exploring the Causal Relationship by Jazmin Seijas Nogarida,2008.
7. Green Marketing and Management: A global Perspective by John F. Whaik, 2005

QUANTITATIVE METHODS FOR ENERGY MANAGEMENT & PLANNING

MODULE-I:

A review of probability concepts, Forecasting and decision making in view of multi-variant techniques, Linear programming, Graphical solution, Simplex method, Duality and post-optimality analysis, Integer programming .

MODULE-II:

Optimal technology mix in micro and macro level energy planning exercises, Sequencing, Queuing theory, Networks, PERT and CPM,

MODULE-III:

Decision theory, Markov analysis, Non linear programming, Decision making with uncertainty, decision making with multiple objectives, Deterministic and probabilistic dynamic programming, Regression analysis.

Text/References

1. Operations Research, An Introduction, Sixth Edition, 2000, by HA Taha, Prentice-Hall of India Pvt. Ltd.

2. Quantitative Techniques in Management, First Edition, 1997, by ND Vohra, Tata McGraw-Hill Publishing Company Ltd, New Delhi.

ADVANCED MICROPROCESSOR AND MICROCONTROLLER

Module-I :16-bit microprocessor(one well known processor, say 8086 to 68000 to be taken as case study)-quick overview of the instruction set, Assembly language programming. Interrupt structure, Interfacing memory and I\O devices. Memory organizations. Standard peripherals and their interfacing-(s\w and h\w aspects) color graphic terminals and ASCII keyboards, mouse, floppy and hard disc drive, other storage media (optical disks, Digital Audio Tapes etc.)

Module-II : Data transfer techniques-Asynchronous and synchronous. Serial and parallel interface standards.Communication media and adapters.Modems and their interfacing.Bus structures and standards-basic concepts.Example of a bus standard (PC\-VME bus). Salient features of other processors (80286\386\486 or 68020\68030\68040).

Module-III : Microcontrollers and digital signal processors. I\O processors and arithmetic coprocessors.Logic design for microprocessor-based systems-design of state.

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

Text/References

1. John.F.Wakerly: Microcomputer Architecture and Programming, John Wiley and Sons.

2. Ramesh S.Gaonker: Microprocessor Architecture, Programming and Applications with the 8085, Penram International Publishing (India).

3. Yu-Cheng Liu and Glenn A.Gibson: Microcomputer systems: The 8086/8088 Family Architecture, Programming and Design, Prentice Hall of India.

4. Raj Kamal: The Concepts and Features of Microcontrollers, Wheeler Publishing.

Publication.

LAB-2

(To Be Decided By The Dept.)