ACADEMIC REGULATIONS
COURSE STRUCTURE
AND
DETAILED SYLLABUS

M.Tech.
Power Engineering and Energy Systems

(Effective for the students admitted from the Academic Year 2007-08)

Jawaharlal Nehru Technological University
Hyderabad – 500 085

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY, HYDERABAD

M.TECH.(POWER ENGINEERING AND ENERGY SYSTEMS) .w.e.f. 2007-08

COURSE STRUCTURE AND SYLLABUS

I SEMESTER

SUBJECT	T	P
Power System Dynamics	4	-
H.V.D.C.Transmission	4	-
Energy Conversion System	4	-
Microprocessor and Micro Controllers	4	-
Elective 1	4	-
Elective 2	4	-
Micro Processors and Micro Controllers Lab		3

II SEMESTER

SUBJECT	T	P
*Renewable Energy Resources	4	-
Advanced Power System Protection	4	-
*Electrical Energy Conservation	4	-
*Instrumentation	4	-
*Elective - 3	4	-
Elective - 4	4	-
(a) Electrical System Simulation (or) (b) Energy Laboratory.		3

* (as of M.Tech (Energy Systems) of centre for Energy Studies)

Elective 1	Elective 2
1. High Voltage Engineering and Insulation co-ordination	1. Analysis of Power Electronic Converters
2 Voltage Stability	2. Modern Control Theory
3. Operation Research	3. Energy Auditing Conservation and Management

Elective – 3	Elective-4
1.Thermal Power Plants	1. Flexible AC Transmission Systems
2. Hydel Power Engineering	2. Extra High Voltage Transmission
3. Energy Management and Thermal Energy Conservation	3. Distribution Automation

III & IV SEMESTERS

SEMINAR

PROJECT

I SEMESTER

POWER SYSTEM DYNAMICS

Unit I

Basic concepts: Power system stability states of operation and system security system dynamics problems system model analysis of steady State stability and transient stability, simplified representation of Excitation control. .

Unit II

Modeling of synchronous machine: synchronous machine park's Transformation -Transformation of flux linkages, Transformation of stator voltage equations and rotor equations.

Unit III

Analysis of steady state performance, per unit quantities - Equivalent circuits of synchronous machine determination of parameters of equivalent circuits.

Unit IV

Excitation system: Excitation system modeling, excitation systems block Diagram system representation by state equations.

Unit V

Dynamics of a synchronous generator connected to infinite bus: system model Synchronous machine model, stator equations rotor equations, Synchronous machine model with field circuit and with field circuit and one equivalent damper winding on q axis (model 1.1), calculation ofInitial conditions.

Unit VI

Analysis of single machine system: small signal analysis with block diagram Representation characteristic equation and application of routh hurwitz criterion

Unit VII

Synchronizing and damping torque analysis, small signal model State equations.

Unit VIII

Application of power system stabilizers: basic concepts in applying PSS, Control signals, structure and tuning of PSS, washout circuit, dynamic compensator analysis of single machine infinite bus system with
and without PSS.

Text book

1. Power system dynamics K.R. P ADIY AR, B.S. Publications Hyderabad

Reference

1. Power system control and stability P.M. Anderson and A.A. Fouad John wiley sons

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I SEMESTER

HIGH VOLTAGE D.C. TRANSMISSION

Unit I
H.V.D.C. Transmission: General considerations, Power Handling CapabiJities of HVDC Lines, Basic Conversion principles, static converter configuration.

Unit II
Static Power Converters: 3-pulse, 6-pulse and 12-pulse converters, converter station and Terminal equipment, commutation process, Rectifier and inverter operation, equivalent circuit for converter - special features of converter transformers.

Unit III
Harmonics in HVDC Systems, Harmonic elimination, AC and DC filters.

Unit IV
Control of HVDC Converters and systems: constant current, constant extinction angle and constant Ignition angle control. Individual phase control and equidistant firing angle control, DC power flow control.

Unit V
Interaction between HV AC and DC systems - Voltage interaction, Harmonic instability problems and DC power modulation.

Unit VI
Multi-terminal DC links and systems; series, para11el and series para11el systems, their operation and control.

Unit VII
Transient over voltages in HVDC systems: Over voltages due to disturbances on DC side, over voltages due to DC and AC side line faults

Unit VIII
Converter faults and protection in HVDC Systems: Converter faults, over current protection - valve group, and DC Jine protection. Over voltage protection of converters, surge arresters.

Reference Books:

1. E.W. Kimbark : Direct current Transmission, Wiely Inter Science New York.

J.Ari11aga : H.V.D.C.Transmission Peter Peregrinus ltd., London UK 1983

2.K.R.Padiyar: High Voltage Direct current Transmission, Wiely Eastern Ltd., New Delhi - 1992.

3.E.Uhlman : Power Transmission by Direct Current, Springer Verlag, Berlin Helberg - 1985.

I SEMESTER

ENERGY CONVERSION SYSTEMS

Unit I

Photo voltaic power generation ,spectral distribution of energy in solar radiation, solar cell configurations, voltage developed by solar cell, photo current and load current, practical solar cell performance, commercial photo voltaic systems, test specifications for pv systems, applications of super conducting materials in electrical equipment systems.

Unit II

Principles of MHD power generation, ideal MHD generator performance, practical MHD generator, MHD technology.

Unit III

Wind Energy conversion: Power from wind, properties of air and wind, types of wind Turbines, operating characteristics.

Unit IV

Tides and tidal power stations, modes of operation, tidal project examples, turbines and generators for tidal power generation. Wave energy conversion: properties of waves and power content, vertex motion of Waves, device applications. Types of ocean thennal energy conversion systems Application of OTEC systems examples,

Unit V

Miscellaneous energy conversion systems: coal gasification and liquefaction, biomass conversion, geothennal energy, thenno electric energy conversion, principles of EMF generation, description of fuel cells

Unit VI

Co-generation and energy storage, combined cycle co-generation, energy storage. Global energy position and environmental effects: energy units, global energy position..

Unit VII

Types of fuel cells, HZ-02 Fuel cells, Application of fuel cells - Batteries, Description of batteries, Battery application for large power.

Unit VIII

Environmental effects of energy conversion systems, pollution from coal and preventive measures steam stations and pollution, pollution free energy systems.

TEXT BOOKS

"Energy conversion systems" by Rakosh das Begamudre, New age international publishers, New Delhi 2000.

"Renewable Energy Resources" by John Twidell and Tony Weir, 2nd edition, Fspon AND Co

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I SEMESTER

MICROPROCESSORS AND MICROCONTROLLERS

Unit I
8086/8088 processors: Introduction to 8086 Microprocessors, ,Architecture, Addressing modes, Instruction set, Register Organization, Assembler directives.

Unit II
Hard ware description: Pindiagram signal description min AND max modes, bus timing, ready AND wait states, 8086 based micro computing system.

Unit III
Special features AND Related Programming: Stack structure of 8086, Memory segmentation. Interrupts, ISR, NMI, MI and interrupt Programming, Macros.

Unit IV
Advanced Microprocessors: Intel 80386 programming model ,memory paging, Introduction to 80486, Introduction to Pentium Microprocessors and special Pentium pro features.

Unit V
Basic peripherals AND Their Interfacing:-Memory Interfacing (DRAM) PPI- Modes of operation of 8255 ,Interfacing to ADC AND DAC.

Unit VI
Special Purpose of Programmable Peripheral Devices and Their interfacing :Programmable interval timer, 8253 , PIC 8259A,display controller Programmable communication Interface *8251,USART* and Exercises.

Unit VII
Microcontrollers : Introduction to Intel 8 bit AND16 bit Microcontrollers, 8051- Architecture, Memory organization, Addressing Modes and exercises

Unit VIII
Hardware description of 8051: Instruction formats ,Instruction sets, interrupt Structure AND interrupt priorities, Port structures AND Operation linear counter Functions ,different Modes of Operation and Programming examples.

TEXT BOOKS :

1."The Intel Microprocessors" Architecture Programming ANDInterfacing by Barry b Brey.
2. Advanced Microprocessors by kemith J Ayala, Thomson publishers.
3. Microcontrollers by kentrith J ayala,Thomson publishers.
Reference Books:
1. Microprocessors AND Interfacing Programming AND Hard ware by DOUGLAS V.Hall
2. Microprocessors AND Microcontrollers by Prof. C.R.Sarma

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I SEMESTER

HIGH VOLTAGE ENGINEERING AND INSULATION CO-ORDINATION
Elective-I

Unit I : Conduction and Breakdown in Gases:
Ionization process, Twonsend's current growth equation, current growth in the secondary processes, Twonsend's criterion for breakdown, streamer theory of breakdown in gases, Paschen law, breakdown in non unifonn fields and corona discharge.

Unit II : Conduction, Breakdown in liquids and solids:
Pure liquids and commercial liquids, conduction and breakdown in pure liquids, breakdown in solids dielectrics, Intrinsic breakdown, Electromechanical breakdown and thennal breakdown.

Unit III : Generation of High Voltage and Currents:
Generation of high D.C. generation of high alternating voltages, generation of impulse voltages, generation of impulse currents, tripping and control of impulse generators

Unit IV : Measurement of high voltage and currents:
Measurement of high d.c.voltages, Measurement of high a.c. and impulse voltages,
Measurement of high d.c., a.c. and impulse currents. Cathoae Ray Oscilloscope for impulse voltage and current measurements.

Unit V : Testing of Materials and Apparatus
Measurement of D.C. resistivity, measurement of dielectric constant and loss factor; partial discharge measurements, testing of insulators, bushing, circuits breakers, transfonners and surge divertors.

Unit VI : Over Voltage Phenomenon Insulation Coordination:
Causes of over voltage, lighting phenomenon, switching over voltages and power frequency over voltages in power systems,

Unit VII : Insulation Coordination:
Principle of insulation coordination on high voltage and extra high voltage power systems.

Unit VIII : Gas insulated substations:
Advantages of Gas Insulated Substations, Comparison of Gas Insulated substations and Air Insulated Substations, Design and Layout of Gas Insulated Substations, Description of Various components in GIS.

TEXT BOOKS:

1. High Voltage Engineering by M.S.Naidu and V.Kamaraju - TMH.
2. High Voltage Engineering fundamentals by Kuffel and Zungel, Elsavier Publications
3. Switchgear By BHEL, TMH

REFERENCES:

1. Fundamentals of Gaseous Ionization and plasma Electronics by Essam Nasser - Wiley - Inter Science.
2. High Voltage Technology by A.L.Alston
3. Gaseous Dielectrics by Arora, TMH

I SEMESTER

VOLTAGE STABILITY
Elective-I

Unit I : Introduction to Voltage Stability
Definitions: Voltage Stability" Voltage Collapse, Voltage Security; Physical relation indicating dependency of voltage on reactive power flow; Factors affecting Voltage collapse and instability; Previous cases of voltage collapse incidences.

Unit II : Graphical Analysis of Voltage Stability
Comparison of Voltage and angular stability of the system; Graphical Methods describing voltage collapse phenomenon: P- V and Q- V curves; detailed description of voltage collapse phenomenon with the help of Q- V curves.

Unit – III : Analysis of Voltage Stability
Analysis of voltage stability on SMLB system: Analytical treatment and analysis.

Unit - IV: Voltage Stability Indices
Voltage collapse proximity indicator; Determinant of Jacobin as proximity indicators; Voltage stability margm.

Unit - V: Power System Loads
Loads that influences voltage stability: Discharge lights, Induction Motor, Air-conditioning, heat pumps, electronic power supplies, OH lines and cables.

Unit - VI: Reactive Power Compensation
Generation and Absorption of reactive power; Series and Shunt compensation; Synchronous condensers, SVC OL TC s; Booster Transformers.

Unit – VII : Voltage Stability Margin
Stabilty Margin: Compensated and'un-comensated systems.

Unit - VIII: Voltage Security
Definition; Voltage security; Methods to improve voltage stability and its practical aspects.

Text Books:
I) *"Performance, operation and control of EHV power transmission system"* - A. CHAKRABAR THY, D.P. KOTARI and A.K.MUKOPADYAY, A.H.Wheeler Publishing, I Edition, 1995.
2) *"Power System Dynamics: Stability and Control"* - K.R.P ADIY AR, II Edition, B.S.Publications.

Reference:
"Power System Voltage Stability"- C.W.TA YLOR, Mc Graw Hill, 1994.

I SEMESTER

OPERATION RESEARCH
Elective – I

Unit I:
Linear Programming Problem: Formulation - Graphical method - Simplex method - Artificial variable techniques - Big-M tune -phase methods

Unit II:
Duality theorem - Dual simplex method - Sensitivity analysis - effect of changes in cost coefficients, Constraint constants, Addition/Deletion of variables AND constraints

Unit III :
Transportation problem - formulation - Initial basic feasible solution methods - Northwest, Least cost AND Vogels methods, MODI optimization - Unbalanced AND degeneracy treatment

Unit IV:
Assignment problem - Formulation - Hungarian method - Variants of assignment problems, Sequencing problems - Flow shop sequencing - n jobsx2 machines sequencing - n jobsx3 machines sequencing Job-shop sequencing - 2 jobsxm machines sequencing - Graphical methods

Unit V:
Game Theory - Introduction - Terminology - Saddle point games - with out Saddle point games - 2x2 games, analytical method - 2xn and mx2 games - graphical method - dominance principle

Unit VI:
Dynamic programming - Bellman's principle of optimality - short route - capital investment - inventory allocation

Unit VII:
Non linear optimization - Single variable optimization problem - Unimodal function - Elimination methods - Fibinocci AND Golden reaction methods - Interpolation methods - Quadratic AND cubic interpotation method.

Multi variable optimization problem - Direct research methods - Univariant method - Pattern search methods - Powell's, Hook-Jeaves AND Rosen-brock's search method.

Unit VIII:
Geometric programming - Polynomial - Arithmetic - Seametric inequality - Unconstrained G:P - Constraint G.P with:S; type constraint.

Simulation: Definition - Types- steps- Simulation of simple electrical systems - Advantages and Disadvantages

TEXT BOOKS:

1. Optimization theory AND Applications - S.S.Rao, New Age Internationals
2. Operations Research - S.D.Sharma, Galgotia publishers
3. Operations Research - Kausur AND Kumar, Spinger Publishers

REFERENCES:

1. Optimization techniques: Theory AND Practice - M.C.Joshi AND K.M. More Ugalya, Narosa Publications
2. Optimization: Theory AND Practice - Beweridze, Mc Graw Hill
3. Simulation Modelling AND Analysis - Law AND Kelton - TMH
4. Optimization Concepts and Applications in Engineering- A.D. Belegundu , lR. Chandrupata, Pearson Education, Asia

I SEMESTER

ANALYSIS OF POWER ELECTRONIC CONVERTERS
Elective II

Unit I Single Phase AC Voltage Controllers.
Single phase AC voltage controllers with Resistive, Resistive-inductive and Resistive-inductive-induced e.m.f. loads - ac voltage controllers with PWM Control - Effects of source and load inductances _ Synchronous tap changersApplications - numerical problems.

Unit II Three Phase AC Voltage Controllers.
Three phase AC voltage controllers - Analysis of controllers with star and delta Connected Resistive, Resistive-inductive loads - Effects of source and load Inductances - applications - numerical problems.

Unit III Cycloconverters.
Single phase to single phase cyc1oconverters - analysis of midpoint and bridge Configurations - Three phase to three phase cyc1oconverters - analysis of Midpoint and bridge configurations - Limitations - Advantages - Applications - numerical problems.

Unit IV Single Phase Converters.
Single phase converters - Half controlled and Fully controlled converters *I* Evaluation of input power factor and harmonic factor - continuous and Discontinuous load current - single phase dual converters - power factor Improvements - Extinction angle control- symmetrical angle controlPWM - single phase sinusoidal PWM - single phase series -converters Applications - Numerical problems.

Unit V Three Phase Converters.
Three phase converters - Half controlled and fully controlled converters Evaluation of input power factor and harmonic factor - continuous and Discontinuous load current - three phase dual converters - power factor Improvements - three phase PWM - twelve pulse converters - applications Numerical problems.

Unit VI D.C. to D.C. Converters.
Analysis of step-down and step-up dc to dc converters with resistive and Resistive-inductive loads - Switched mode regulators - Analysis of Buck Regulators - Boost regulators - buck and boost regulators - Cuk regulators Condition for continuous inductor current and capacitor voltage - comparison Of regulators -Multiouput boost converters - advantages - applications Numerical problems.

Unit VII Pulse Width Modulated Inverters(single phase).
Principle of operation - performance parameters - single phase bridge inverter voltage and current with resistive, inductive and Capacitive loads - Voltage control of single phase inverters - single PWM - Multiple PWM - sinusoidal PWM - modified PWM - phase displacement evaluation of output Control - Advanced modulation techniques for improved performance Trapezoidal, staircase, stepped, harmonic injection and delta modulation Advantage - application - numerical problems.

Unit VIII Pulse Width Modulated Inverters(three phase).

Three phase inverters - analysis of 180 degree condition for output voltage And current with resistive, inductive loads - analysis of 120 degree Conduction - voltage control of three phase inverters - sinusoidal PWM Third Harmonic PWM - 60 degree PWM - space vector modulation - Comparison of PWM techniques - harmonic reductions - Current Source Inverter - variable d.c. link inverter - boost inverter - buck and boost inverter - inverter circuit design - advantages - applications - numerical problems.

Textbooks:

Power Electronics - Mohammed H. Rashid - Pearson Education -Third Edition - First Indian reprint 2004.

Power Electronics - Ned Mohan, Tore M. Undeland and William P. Robbins - John Wiley AND Sons
Second Edition.

I SEMESTER

MODERN CONTROL THEORY
Elective – II

UNIT -I MATHEMATICAL PRELIMINARIES
Fields, Vectors and Vector Spaces - Linear combinations and Bases - Linear Transfonnations and Matrices - Scalar Product and Nonns - Eigenvalues, Eigen Vectors and a Canonical fonn representation of Linear operators - The concept of state - State Equations for Dynamic systems - Time invariance and Linearity - Nonuniqueness of state model- State diagrams for Continuous-Time State models.

UNIT- II STATE VARIABLE ANALYSIS
Linear Continuous time models for Physical systems- Existence and Uniqueness of Solutions to Continuous- Time State Equations - Solutions of Linear Time Invariant Continuous-Time State Equations - State transition matrix and it's properties.

UNIT-III CONTROLLABILITY AND OBSERV ABILITY
General concept of controllability - General concept of Observability - Controllability tests for Continuous- Time Invariant Systems - Observability' tests for Continuous-Time Invariant Systems - Controllability and Observability of State Model in Jordan Canonical fonn - Controllability and Observability Canonical fonns of State model.

UNIT- IV NON LINEAR SYSTEMS-I
Introduction - Non Linear Systems - Types ofNon-Linearities - Saturation - Dead-Zone - Backlash-Jump Phenomenon etc;- Singular Points - Introduction to Linearization of nonlinear systems, Properties of Non-Linear systems - Describing function-describing function analysis of nonlinear systemsStability analysis of Non-Linear systems through describing functions

UNIT-V NON LINEAR SYSTEMS-II
Introduction to phase-plane analysis, Method of Isoclines for Constructing Trajectories, singular points, phase-plane analysis of nonlinear control systems.

UNIT-VI STABILITY ANALYSIS
Stability in the sense of Lyapunov, Lyapunov's stability and Lypanov's instability theorems - Stability Analysis of the Linear continuous time invariant systems by Lyapunov second method - Generation of Lyapunov functions - Variable gradient method - Krasooviski's method.

UNIT-VII STATE FEEDBACK CONTROLLERS AND OBSERVERS
State feedback controller design through Pole Assignment - State observers: Full order and Reduced order

UNIT - VIII
Introduction to optimal control - Fonnulation of optimal control problems - calculus of variations - fundamental concepts, functionals, variation of functionals - fundamental theorem of theorem of Calculus of variations - boundary conditions - constrained minimization - fonnulation using Hamiltonian method - Linear Quadratic regulator

TEXT BOOKS: 1. Modem Control System Theory by M.Gopal- New Age Intemational-1984
1. Modern Control Engineering by Ogata.K - Prentice Hall - 1997

REFERENCES:
1. Optimal control by Kircks

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I SEMESTER

ENERGY AUDITING, CONSERVATION AND MANAGEMENT
Elective-II

Unit I Basic principles of Energy audit
Energy audit- definitions, concept, types of audit, energy index, cost index ,pie charts, Sankey diagrams, load profiles, Energy conservation schemes- Energy audit of industries- energy saving potential, energy audit of process industry, thermal power station, building energy audit

Unit II Energy management
Principles of energy management, organizing energy management program, initiating, planning, controlling, promoting, monitoring, reporting- Energy manger, Qualities and functions, language, Questionnaire - check list for top management

Unit III Energy efficient _otors
Energy efficient motors, factors affecting efficiency, loss distribution, constructional details, characteristics _ - variable speed, variable duty cycle systems, RMS hp- voltage variation-voltage unbalance- over motoring'-' motor energy audit

Unit IV Power Factor Improvement, Lighting and energy instruments
Power factor - methods of improvement, location of capacitors, Pf with non linear loads, effect of harmonics on p.f. , p.f motor controllers - Good lighting system design and practice, lighting control ,lighting energy audit - Energy Instruments- watt meter, data loggers, thermocouples, pyrometers,lux meters, tongue testers ,application of PLC's

Unit V Economic aspects and analysis
Economics Analysis-Depreciation Methods, time value of money, rate of return, present worth method, replacement analysis, life cycle costing analysis- Energy efficient motors- calculation of simple payback method, net present worth method- Power factor correction, lighting - Applications of life cycle costing analysis, return on investment.

Reference Books:
Energy management by W.R. Murphy AND G. Mckay Butter worth, Heinemann publications.
Energy management by Paulo' Callaghan, Mc-graw Hill Book company-1 st edition, 1998
Energy efficient electric motors by John .C. Andreas, Marcel Dekker Inc Ltd-2nd edition, 1995
Energy management hand book by W.C.Turner, John wiley and sons
Energy management and good lighting practice: fuel efficiency- booklet12-EEO

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I SEMESTER

MICROPROCESSORS AND MICRO CONTROLLERS LAB

LIST OF EXPERIMENTS

I. Microprocessor 8086

1) Introduction to MASM / T ASM
2) Arithmetic operations: Multi byte addition, subtraction, Multiplication and Division, Signed and Unsigned Arithmetic operation, ASCII - arithmetic.
3) Logic operations: Shift and rotate - converting packed BCD to unpacked BCD, BCD to ASCII conversion.
4) By using string operation and instruction prefix - Move block, reverse string, sorting, inserting, deleting, length of string, string comparison.
5) Modular programming - Procedure, near and far implementation, recursion.
6) DOSIBIOS programming - Reading key board (buffered with and without echo) - display characters, string.

II Interfacing to 8086
1) 8259 - interrupt controller
2) 8279 - keyboard / display
3) 8255 - PPI
4) 8251 - USART
5) Stepper Motor
6) Traffic light control
7) GPIB (IEEE 488) Interface
8) Numeric printer interface
9)RTC interface
10)AID and D/A
1) DMA interface
2) FDC-EPROM Programmer Interface

III. Microcontroller 8051
1) Reading and writing on a parallel port
2) Timer in different modes
3) Serial communication implementation
4) Understanding three memory areas of OO-FF (Programs using above areas) 5) ing external interrupts
1) Programs using special instructions like SWAP, Bit/Byte, Set/ Reset etc.
2) Program based on sort, Page, absolute addressing.

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II SEMESTER

RENEWABLE ENERGY RESOURCES

I. Solar Energy - Availability - Solar radiation data and measurement - Estimation of average solar radiation - Solar water heater types - Heat balance - Flat plate collector efficiency - Efficiency of heat removal - Thermo siphon flow calculation - Forced circulation calculation - Evacuated collectors - Basics of solar concentrators

2. Solar Energy Applications - Solar air heaters - Solar Chimney - Crop driers - Passive solar system - Active solar systems - Water desalination - Output from solar still - Principle of solar ponds. .

3. Wind Energy - Nature of wind- Characteristics - Variation with height and time - Power in wind - Aerodynamics of Wind turbine - Momentum theory- Basics of aerodynamics - Aerofoils and their characteristics - HA WT - Blade element theory - Prandtl's lifting Hne theory (prescribed wake analysis) VA WT aerodynamics - Wind turbine loads - Aerodynamic loads in steady operation- Yawed operation and tower shadow. .

4. Wind Energy Conversion System - Siting - Rotor selection - Annual energy output - Horizontal . axis wind turbine (HA WT) - Vertical axis wind turbine (V A WT) - Rotor design considerations Number of blades - Solidity - Blade profile - Upwind/Downwind - Yaw system - Tower - Braking system - Synchronous and asynchronous generators and loads - Integration of wind energy . converters to electrical networks - Inverters - Control system - Requirement and strategies - Noise - Applications of wind energy

5. Biomass energy - Bio fuel classification – Examples of thermo chemical,pyrolysis,biochemical and agrochemical systems - Energy farming – Direct combustion for heat - Process heat and electricity - Ethanol production and use - Anaerobic digestion for biogas - Different digesters Digester sizing. Applications ofBiogas - Operation with I.C.Engine .

6. Ocean Energy - OTEC Principle - Lambert's law of absorption - Open cycle and closed cycle heat exchanger calculations - Major problems and operational experience.

7. Tidal Power - Principles of power generation - components of power plant - Single and two basin systems - Turbines *for* tidal power - Estimation of energy - Maximum and minimum power ranges - tidal powerhouse.

Wave Energy - Concept of energy and power from waves - Wave characteristics - period and wave velocities - Different wave energy conservation devices (Saltor duck, oscillating water column and dolphin types) - operational experience.

8. Geothermal Energy - Classification- Fundamentals of geophysics - Dry rock and hot aquifier energy analysis - Estimation of thermal power - Extraction techniques - Prime movers.

REFERENCES:

Renewable Energy Resources / John Twidell and Tony Weir / E & F.N.Spon
,Renewable Energy Resources Basic Principles and Applications / G.N.TiWariand M_K.Ghosai / i Narosa
Solar Energy - Principlesgfthermal coUecti<,?n and storage/ S.P. Sukhatme / TMH
Solar Energy ThermalProcesses,IDuffie & Beckman
Solar Heating and Cooling / Kreith & Kreider
Wind Energy Handbook / Tony Burton, David Sharpe, Nick Jenkins and Ervin Bossanyj / Wiley.
Wind Electrical Systems / S.N.Bhadra, D.Kastha and S.Banerjee / OKford
Biogas Technology - A Practical Hand Book / K.Khendelwal & 8.S. Mahdi / McGraw-Hill

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II SEMESTER

ADVANCED POWER SYSTEM PROTECTION

Unit I:
Primary and back up protection, current transformers for protection, potential transformer, review of electromagnetic relays static relays.

Unit II:
Over current relays time current characteristic, current setting time setting, directional relay, static over current relays.

Unit III:
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.

Unit IV:
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.

Unit V:
Digital relaying algorithms, differential equation technique, discrete fourier transform technique, walshhadamard transform technique, rationalized harr transform technique, removal of dc offset

Unit VI :
Introduction to Microprocessors: review of microprocessors and interfacing. single chip microcomputers programmable interval timer, *AID* converter.

Unit VII :
Microprocessor based protective relays: over current, directional, impedance, reactance relays. Generalized mathematical expressions for distance relays, mho and offset mho relays, quadrilateral relay.

Unit VIII:
Microprocessor implementation of digital distance relaying algorithms.

Text book
1. Power system protection AND switchgear by Badri ram AND vishwakarma, TMH publication New Delhi 1995.
2. Power System Protection by Madhava Rao TMH

Reference Books
1. Power System by Ravindra Nath and Chandar PHI.

II SEMESTER

ELECTRICAL ENERGY CONSERVATION

1. Three Phase Induction Motors - Cage motors, - equivalent circuit - Speed - torque characteristics performance characteristics - voltage unbalance - over motoring - slip ring induction motor characteristics multi speed motors.

2. Single Phase Induction Motors - starting & running performance - Split phase - Capacitor type motors Characteristics - Reluctance motors -Universal motors -. Applications

3. Energy Efficient Motors - Constructional details – Factors affecting effifiency - Losses distribution - Characteristics- Calculation of pay back period.

4. Power Factor - . Causes and disadvantages of low power factor - Methods to improve p.f - Economics of power factor improvement - Simple pay back method - Return on investment - Life cycle analysis

5: Energy efficient lighting - Terminology - Cosine law of luminance - Types *of* lamps - Characteristics- Design of illumination systems - ' Good lighting practice – Lighting control – Steps for lighting energy conservation.

6. Economics Of Electrical Energy Generation.& Audit - Definitions - Connected load, Maximum demand - Demand factor - Diversity factor - Significance - Load curve - Load sharing between base load and peak loads - Electrical Energy Audit: Check List - Data Collection - Data Analysis - Case Studies. .

7. Economics *Of* Electrical Energy Distribution – Electrical load analysis - types of consumers & tariffs.- line losses –corona losses -: types of distribution system - Kelvin's law - loss load factor.

8. Economics of Electrical Drives - Selection of motors - types of loads - Energy Consumption during starting of a.c and d.c motors - Braking of d.c and a.c motors- Plugging - Regenerative braking. ,.

REFERENCES:

a.'" Electrical Machinery / Fitzgerland, KingSley, Kusko /Mc Graw Hill Ltd.
b.Energy EffiCient ElectriCal motors / Jonn C.Ahdreas / Marcel Dekker Jnc.
c. Electrical Technology/ Edward Hughes /ELBS.
d. Energy Management and good lighting practice: Fuel Efficiency Booklet 12/ EEO.
e. Generation, distribution & utilization of Electrical Energy *I* CL Wadhwa *I* Wiley Eastern Ltd.

II SEMESTER

INSTRUMENTATION

1. Measurement and Characterstics: Elements of. a Measurement System; Classification of Instruments; Static Performance Parameters; Loading and Impedance Matching; Errors and Uncertainties in Measurement; Process and Standards of Calibration; Dynamic Characteristics - Transfer Function Representation of a Measurement System, Impulse and Step Responses of First and Second Order Systems, Frequency Response of First and Second Order Systems.

2.Mechanical Transducers: Temperature- Bimetallic Element' and Fluid Expansion type Thermometers; Pressure - Manometers and Bourdon Gauges; Force- Balances, Helical Spiral Springs, Lead. Cells and Elastic Force Devices; Torque- Torsion Bars and Flat Spiral - Springs; Liquid Level-Float Systems and Level to Pressure Converters; Flow- Pitot Static Tubes and Turbine type Flow Meters.

3. Passive Electrical Transducers:- Resistance Thermometers; Interfacing Resistive Transducers to Electronic Circuits; Thermistors- Measurement of Temperature and Thermal Conductivity, Temperature Control; Resistance Strain Gauges- Gauge Factor, Bonded and Unbonded Strain Gaug_s; Self Generating and" Non Self Generating Inductive Transducers; Linear Variable Differential Transformers; Capacitive Transducers_

4. Active Electrical Transducers: Potentiometric Transducers; T}1ermoelectric Transducers and Sources of Errors in Thermocouples; Piezoelectric and Magnetostrictive Transducers; Photoelectric Transducers- Photoemissive, Photoconductive and Photovolt_ic types; Electromechanical Transducers'- Tachometers, Digital Transducers-Electromagnetic Frequency Domain and _Optoelectrical Frequency Domain Transduc_rs, Vibrating String Transducers, Digital Encoders, Digital Tachometers.

5. Basic Signal Conditioning Elements: Amplifiers- Non Electrical and Electrical types; Op Amps-Inverting, Non Inverting, Summing, Differential, and Charge Amplifiers; Differentiating and Integrating Elements; Filters; A to D and ID to A Converters- Potentiometric, Dual Slope and Counting types; Data Transmission Elements,. Electrical, Pneumatic, Position and Radio Frequency Transmission types; Compensation Elements for First and Second Order Systems.

6. Basic Indicating, Recording, and Display Elements: Feedback in Instrume,nts- Principles of Feedliack'and Advantages & Disadvantages of feedback; Digital Voltmeters-Ramp and Dual Slope types; Cathode Ray Oscilloscopes; Galvanometric, Servo type Potentiometric and Magnetic Tape Recorders; Digital Recorders of Memory type; Data Displays-Analog and Digital types.

7. Advanced Measuring Techniques: Temperature- Total and Selective Radiation type Pyrometers ; Pressure- High Wire Pressure Transducers; Mcleod Gauge, Ignization Gauge; Flow- Ultrasonic and Electromagnetic Flow Meters, Hot Wire Anemometer,1.aser Doppler Anemometer, Particle Image Velocimetry; Condition Monitoring and Signature Analysis- Vibration & Noise, Wear and Corrosion Monitoring, Selection of Condition Monitoring Techniques.

8. Emerging Developments in Instrumentation: Computer Aided Measurements- Block Diagram of a typical Computer Controlled Measurement System, Microcomputers for Data Acquisition, Data Transfer and Communication; IEEE 488 Electrical Interface- Instruments used in Computer Controlled Measurement; Fiber Optic Transducers; Microsensors- Silicon an_ Hall Effect Sensors; Smart Sensors; Smart Transmitters and Field Bus.

Reference Book:

Albert D Helfrick and William D Cooper; Modern Electronic Instrumentation and Measurement Techniques; 2004, PHI , www.phindia.com

BC Nakra and KK Chaudhry; Instumentation, Measurement and Analysis; 2ed, 2004, Tata McGraw Hill, www.tatacgrawhill.com

DVS Murthy; Transducers and Instrumentation;2003, PHI, www.phindia.com

CS Rangan, GR Sarma and VSV Mani; Instrumentation Devices and Systems; 2ed Tata McGraw Hill

Doeblin and Ernest; Measurement Systems Application and Design; 5ed 2004, Tata McGraw Hill.

II SEMESTER

THERMAL POWER PLANTS
Elective – III

1. Fuels and Combustion - Types of fuels - Coal firing - Pulverization of solid fuels - Fuel handling systems - Coal cycle - Ash cycle – Types of Furnaces - Fluidized bed combustion (FBC) - Liquid and gaseous fuels - By products of combustion - Synthetic fuels - Heat of combustion - Combustion temperatures - Stack

2. Steam Generators and Accessories - Steam generators - Classification - types .-- high pressure boilers - Super critical boilers - Steam piping Accessories - Super heaters - Reheaters Economizers - Air Preheaters - Pumps and Fans

3. Steam Turbines - Classification – HP/IP/LP Turbines - Impulse turbjnes - Reaction turbines - - Compounding - Steam compounding - Velocity compounding - Advantages and disadvantages - Governing- Turbine losses - Turbine efficiencies - Turbine troubles - Turbine materials

4. Gas Turbines - Gas Turbine cycle - Combined cycle analysis - Design for high temperature combined cycles with heat recovery boiler - STAG combined cycle power plant""" Combined cycle with multi pressure steam, Influence of component efficiencies on cycle performance - Combined cycle with Nuclear power plant - ICGCC plant .

5 Condensers - Types - direct contact condensers-surface condensers - Feed water Heaters - Types - Boiler Makeup - Evaporators

6. Condensate circulation system - Cooling towers - Types - wet cooling towers-wet cooling towers - dry cooling towers. .

7. Power Plant Layout and Economics - General layout of modern thermal power plants Advanced layouts - Fossil fuel resources in India - Prospects of thermal power in India Generation demand gap - Methods to bridge the gap - Plant efficiency and economics

. 8. Environmental aspects of thermal power plants .. Constituents of the atmosphere -Dust collectors - Oxides of Sulfur, Nitrogen and Carbon - Greenhouse effect - Acid precipitation - Particulate matter - Electrostatic precipitators _ Thermal pollution .

References:

"A course in Power Plant Engineering! Arora and Domkundwarl DhanpatRai Power Plant Engineering *I* G.R. NagpaVKhanna Publishers
Power Plant Technology *I* El Wakill McGraw Hill
Power Plant Technologyl Rajput/
Power Plant Engineering *I* P .K.Nag *I* Tata McGraw Hill

II SEMESTER

HYDEL POWER ENGINEERING
Elective III

1. Basic Concepts - Importance of Hydro-electric power - Investigations and studies for waterpower development. Load Study and Estimation - Available power - Power duration curve - Storage and pondage - Firm power- Secondary power - Load duration curve.

2. Power Development - Run-Of-River power development -Types of plants - Mini and Micro , hydel power development- Components of run-of-river power development on canal; falls ;. Pumped Storage Power Development - Essential requirements - Necessity - Advantages , Classification of PSP development, Components - Layout - Economics -_ Cost of power generated.

3. Design and Construction of Hydro-Electric Works - Layout of scheme - Design of intakes - Penstocks - Economic diameters of penstocks - Design of anchor blocks - Air vents -.Water hammer problems - Types of Surge tanks - 'Functions, Location and Types, Fore Bay - Stability of , surge tanks '

4. Principles of Hydraulic Machinery - Dynamic Force exerted "by Fluid Jet on stationary Flat plate - Plate normal to jet and inclined plate - Fluid jet on curved' plate - Fluid jet on moving curved surface of a turbine blade - Velocity diagrams for turbine blades - Work done on Tangential flow' turbine Runner "Angular Momentum equation - Radial flow -' Power produced by Radial runner.

5. Hydraulic Prime Movers-l - History of Development of water wheel and Water Turbines - Classification of Modem Water Turbines - Impulse Turbines, Main components and their Functions. - Modem Pelton turbine – Arrangements of jets - Runner - Turbine shaft - Design of components of Pelton Turbine- Force, Power and efficiency - Velocity Triangles - Force exerted by jet –Work done and Power Developed by jet - Turbine Efficiencies, ..

6. Hydraulic Prime Movers-2 - Modem Francis Turbine - Main Components - Design - Shapes of Francis Runner and Evolution of Kaplan Runner - Draft tube Theory – cavitation- Torque - Power and Efficiencies - Propeller, Kaplan and tubular (or Bulb) Turbines- Force - Torque - Power and' Efficiencies - Types of Governors, Governing of Impulse and Reaction' Turbines.

7. Modeling and testing of turbines - Models and Selection of Turbines - Turbo Models and their Testing, Similarity considerations of Model and Proto type Turbines - Geometric, Kinematics and Dynamic Similarities - Performance characteristics. .

8. Power Station Planning - Power plant structure - Layout of hydro power plants- Types of power houses -Under ground power houses - Investigation and studies - Safety requirements - Sizing of a power house;

REFERENCES:

a. Fluid Mechanics And Fluid Power Engineering *I* D.S.Kumar
b. Water Power Engineering *IM.* M. Dandekar & K. N. Sharma
c. Fluid Power with Application *I* Anthony Esposito 5th Ed.
d. Hydraulic Machines! T.R. Banga & S.c. Sharma'
e. A text Book of Water Power Engineering *I* R.K.Sharma & T.K.Sharma

II SEMESTER

ENERGY MANAGEMENT AND THERMAL ENERGY CONSERVATION
Elective - III

I. Energy Management - Definition - Scope of Energy Management - Necessary steps in Energy Management Programme - General Principles of Energy Management - Qualities of Energy Manager - Functions of Energy Manager - Language of Energy Manager.

2. Energy Audit - Definition - Energy surveying and Auditing - Objectives - Control of Energy Uses of Energy - Energy conservation schemes -Energy index - Cost index - Pie charts - Sankey diagrams - Load profiles (Histograms) - Types of energy audits -:' General energy audit -- Detailed energy audit - Questionnaire - Energy saving potential.

3. Energy Conservation - Definition - Indian Energy Conservation. Act, 200 I - Rules for efficient energy conservation of energy and materials - Technologies for energy conservation - (Reducing demand using alternative supplies, Load factor, balancing and Energy storage) - Indian. Electricity Act.

4. Design for conservation of Energy and Materials (Simulation and Modeling, Energy flow networks, Critical assessment of energy usage, Formulation of objectives and constraints, Synthesis of alternative options, Technical analysis of options).

5. Heat Exchangers- Classification - Over all heat transfer coefficient - Fouling factor - Concept of caloric temperature - Correction factors for Cross flow and 1-2 heat exchanger - Design of _t exchangers by L.M.T.D. and N.T.U. methods. Liquid-to-Liquid heat exchangers - Double pipe - Series-Series type - Series Parallel type - Shell and tube Heat exchanger.

6. Heat Exchanger Networks - Process integration -Concepts of Pinch technology Identifying Energy Saving.- Heat exchanger networks (HEN) - Simple treatment.

7. Heat Recovery Systems - Sources of waste heat - Guidelines to identity waste heat - Grading of Waste heat - Feasibility study of waste heat recovery - Gas to Gas heat recovery - Rotary generators - Heat pipes - Gas to liquid heat recovery - Waste heat boilers -Incinerators - Heat pump.

8. Energy Conservation In .Industries - General list of equipment -. List of energy intensive industries - Guidelines for identification of loses - Methodology *of* energy conservation in various equipment .

References:

a. Energy Conservation/PaulO' CaUaghanl1981.
b. Energy Management! PaulO' Callaghanl Me Graw HiW 1992
c. Heat Recovery Systems / D.A.Reay *I* E andF.N.Spon /1979
d. Energy Management, *I* Murphy W.R. and Mckay 0/ Butterworth London, 1982.
e. Handbook of Energy Audits *I* Albert Thumann Ifhe Fairmont Press Inc., Atlanta Gergia, 1979. f. Plant Engineers arid Managers guide to Energy Conservation {Albert ThUmatm *I* Nost and Reinhold Co., New York. .
g. Energy Management Principl_ *I* Craig B. Smith /Pergamon Press

II SEMESTER

FLEXIBLE AC. TRANSMISSION SYSTEMS
Elective – IV

Unit I: FACTS Concepts:
Transmission interconnections power flow in an AC system, loading capability limits, Dynamic stability considerations, importance of controllable parameters basic types of FACTS controllers, benefits from FACTS controllers. .

Unit II:Voltage Source Converters:
Single phase three phase full wave bridge converters transformer connections for 12 pulse 24 and 48 pulse operation.

Unit III : Three level voltage source converter, pulse width modulation converter, basic concept of current source Converters, comparison of current source converters with voltage source converters.

Unit IV: Static Shunt Compensation:
Objectives of shunt compensation, mid point voltage regulation voltage instability prevention, improvement of transient stability, Power oscillation damping,

Unit V: Methods of controllable var generation, variable impedance type static var generators switching converter type var generators hybrid var generators.

Unit VI: SVC and STATCOM: The regulation and slope transfer function and dynamic performance, transient stability enhancement and power oscillation damping operating point control and summary of compensator control.

Unit VII: Static Series Compensators: concept of series capacitive compensation, improvement of transient stabillity, power oscillation damping

Unit VIII: Functional requirements. GTO thyristor controlled series capacitor(GSC) , thyristor switched series capacitor(TSSC), and thrystor controlledseries capaci- tor(TCSC) control schemes for GSC TSSC and TCSC.

Text Book:
1."Understanding FACTS Devices" N.G. Hingorani and L. Guygi. IEEE Press Publications *2000.*

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II SEMESTER

EXTRA HIGH VOLTAGE TRANSMISSION
Elective-IV

Unit I : E.H.V. A.c. Transmission line trends and preliminary aspects standard transmission voltages power handling capacities and line losses - mechanical aspects.

Unit II : Calculation of line resistar.ce and inductances: resistance of conductors, temperature rise of conductor and current carrying capacity. Properties of bundled conductors and geometric mean radims of bundle, inductance of two conductor lines and multi - conductor lines, Maxwell's coefficient matrix.

Unit III : Line capacitance calculation: capacitance of two conductor line, and capacitance of multi conductor lines, potential coefficients for bundled conductor lines, sequence inductances and capacitances and diagonalization.

Unit IV : Calculation of electro static field traveling waves due to corona - Audio noise die to corona, its generation, characteristics and limits measurement of audio noise.

Unit V : Surface voltage Gradient on conductors, surface gradient on 2 conductor bundle and consine law, Maximum surface voltage gradient of bundle with more than 3 sub conductors, Mangolt formula.

Unit VI : Corona: Corona in EHV lines - corona loss formulate - attenuation of traveling waves due to corona - Audio noise due to corona, its generation, characteristics and limits measurement of audio noise.

Unit VII : Power Frequency voltage control: Problems at power frequency, generalized constants. No load voltage conditions and charging currents, voltage control using synchronous conductor, cascade connection of components: Shunt and series compensation, sub synchronous resonance in series capacitor compensated lines

Unit VIII: Static reactive compensatiog systems: Introduction, SVC schemes, Harmonics injected in to network by TCR, design of filters for suppressing harmonics injected in to the system.

Reference Books:

1.Extra High Voltage AC Transmission Engineering - Rakosh Das Begamudre, Wiley Eastern ltd., New Delhi - 1987.
2. EHV Transmission line reference book - Edision Electric Institute (GEe) 1986.

II SEMESTER

DISTRIBUTION AUTOMATION
Elective-IV

Unit I: Distribution Automation and the utility system:
Introduction to Distribution Automation (DA), control system interfaces, control and data requirements, centralized (Vs) decentralized control, DA System (DAS), DA Hardware, DAS software.

Unit II: Distribution Automation Functions: DA capabilities, Automation system computer facilities, management processes, Information management, system reliability management, system efficiency management, voltage management, Load management.

Unit III: Communication Systems for DA : DA communication requirements, Communication reliability, Cost effectiveness, Data rate requirements, Two way capability, Ability to communicate during outages and faults, Ease of operation and maintenance, Conforming to the architecture of data flow

Unit IV: Communication systems used in DA : Distribution line carrier (Power line carrier), Ripple control, Zero crossing technique, telephone, cable TV, Radio, AM broadcast, FM SCA, VHF Radio, UHF Radio, Microwave satellite. fiber optics, Hybrid Communication systems, Communication systems used in field tests.

Unit V: Technical Benefits: DA benefit categories, Capital deferred savings, Operation and Maintenance savings, Interruption related savings, Customer related savings, Operational savings, Improved operation, Function benefits, Potential benefits for functions, function shared benefits, Guide lines for formulation of estimating equations

Unit VI:Parameters required, economic impact areas, Resources for determining benefits impact on distribution system, integration of benefits into economic evaluation.

Unit VII: Economic Evaluation Methods: Development and evaluation of alternate plans, Select study area, Select study period, Project load growth, Develop Alternatives, Calculate operating and maintenance costs, Evaluate alternatives.

Unit VIII: Economic comparison of alternate plans, Classification of expenses and capital expenditures, Comparison of revenue requirements of alternative plans, Book Life and Continuing plant analysis, Year by year revenue requirement analysis, short term analysis, end of study adjustment, Break even analysis, Sensitivity analysis computational aids.

REFERENCE :

IEEE Tutorial Course "Distribution Automation"
IEEE Working Group on "Distribution Automation"

II SEMESTER

ELECTRICAL SYSTEMS SIMULATION LAB

1. Write program and simulate dynamical system of following models:
a) I/O Model
b) State variable model
Also identify time domain specifications of each.

2. Obtain frequency response of a given system by using various methods:
(a) General method of finding the frequency domain specifications.
(b) Polar plot
(c) Bode plot
Also obtain the Gain margin and Phase margin.

3. Determine stability of a given dynamical system using following methods.
a) Root locus
b) Bode plot
c) Nyquist plot
d) Liapunov stability criteria

4. Transform a given dynamical system from I/O model to state variable model and vice versa. 5. Obtain model matrix of a given system, obtain its diagonalize form if exists or obtain Canonical form of system.

6. Write a program and implement linear quadratic regulator
7. Design a compensator for a given systems for required specifications.
8. Conduct a power flow study on a given power system.
9. Design a PID controller.
10. Conduct a power flow study on a given power system network using Guass-Seidel iterative method.
11. Develop a program to solve Swing Equation.
12. Develop a Simulink model for a single area load frequency problem and simulate the same.
13. Develop a Simulink model for a two-area load frequency problem and simulate the same.
14. Design a PID controller for two-area power system and simulate the same.
15. PSPICE Sil)1Ulation of Single phase full converter using RLANDE loads.
16. PSPICE Simulation of Three phase full converter using RLANDE loads.
17. PSPICE Simulation of Single phase AC Voltage controller using RL load.
18. PSPICE Simulation of Three phase inverter with PWM controller.
19. PSPICE Simulation of resonant pulse commutation circuit.
20. PSPICE Simulation of impulse commutation circuit.

II SEMESTER

ENERGY LABORATORY

Study of

a. Operational experience on i) Pyranometer, ii) Sunshine recorder
b. Measurement of speed using Tachometer, Stroboscope and anemometers
c. Measurement of temperature using Infrared Thermometers
d. Measurement of illumination using Lux meter
e. Exhaust gas analysis using gas analyzer

List of experiments:

1. Performance evaluation of a solar flat plate thermosyphon water heating system
2. Conversion efficiency of a solar flat plate forced circulation water heating system
3. Conversion efficiency of a solar Concentrating water heating system
4. Determination of conversion efficiency of a solar air heating system
5. Study and analysis of a solar still / distillation plant
6. Performance estimation of photovoltaic water pumping system
7. Investigation on a solar dryer
8. Operational characteristics of P.V.Indoor lighting system
9. Determination of characteristics of a wind generator
10. Performance evaluation of solar cooker
11. Demonstration of Strirling engine using biomass
12. Performance evaluation of an IC Engine with alternate fuel