# R23 Course Structure
(M.Tech-Power Electronics & Electrical Drives)

## I SEMESTER

<table>
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<tr>
<th>S.No.</th>
<th>Course code</th>
<th>Course Title</th>
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### Laboratory Courses

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### III SEMESTER

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### List of Open Elective Courses offered by EEE Department

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<td>23PE82</td>
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### List of Courses offered under Audit Course

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<td>23AC08</td>
<td>Personality Development through Life Enlightenment Skills</td>
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Detailed Syllabus
Pre-requisites: Power Electronics
Course Educational Objective: This course enables the student to illustrate advanced converter techniques and their control using various modulation techniques in modern power electronic systems.

Course Outcomes: At the end of the course, student will be able to:
CO1: Analyze the performance of controlled rectifiers
CO2: Understand the operation of dc choppers
CO3: Analyze the performance of ac voltage controller and inverters
CO4: Illustrate the operation of various multi level inverters.

UNIT- I: CONTROLLED RECTIFIERS
Review of 1-phase rectifiers, standards for harmonics in single-phase rectifiers, single-phase boost rectifier, voltage doubler PWM rectifier, PWM rectifier in bridge connection, applications of unity power factor rectifiers, three-phase controlled rectifiers-line-commutated controlled rectifiers, power factor, harmonic distortion, special configurations for harmonic reduction, harmonic standards and recommended practices, force-commutated three-phase controlled rectifiers-basic topologies and characteristics, numerical problems.

UNIT- II: DC CHOPPERS
Principle of operation, control strategies, step up and step down choppers, analysis of class A and class B choppers, chopper classification, analysis of one quadrant, two quadrant and four quadrant choppers, derivation of load voltage and current expressions, numerical problems.

UNIT- III: AC-AC CONVERTERS
Single phase AC voltage controllers with PWM control-effects of source and load inductances-synchronous tap changers-three Phase AC voltage controllers-analysis of controllers with star and delta connected R and RL load-effects of source and load inductances-analysis of single phase and three-phase cyclo converters with R and RL loads, numerical problems.

UNIT – IV: DC-AC CONVERTERS
Voltage source and current source inverters- voltage control of single-phase inverters-sinusoidal PWM-modified PWM-phase displacement control-trapezoidal, staircase, stepped, harmonic injection and delta modulation-voltage control of three-phase inverters- sinusoidal PWM-third harmonic PWM-hysteresis current control PWM- space vector modulation-Comparison of PWM techniques-current source inverters-variable dc link inverter-numerical problems.

UNIT – V: MULTI LEVEL INVERTERS
Introduction, multilevel concept, types of multilevel inverters-diode clamped multilevel inverter, principle of operation, features of diode clamped inverter, improved diode clamped inverter-flying capacitors multilevel inverter, cascaded multilevel inverter, modular multilevel converter.

TEXT BOOKS:

REFERENCES:
Pre-requisites: Power Electronics and Solid State Drives

Course Educational Objective: This course enables the student to provide knowledge on steady state analysis & transient analysis of various motor drives and also design and analysis of different advanced power converters to control DC & AC motor drives.

Course Outcomes: At the end of the course, student will be able to:
CO1: Examine the steady state analysis of electric drives
CO2: Analyze current and speed controllers for solid state drives
CO3: Identify the factors that affect the speed control of induction motor drive
CO4: Analyze slip power recovery schemes

UNIT – I: CONVERTER CONTROLLED DC MOTOR DRIVES
Steady state analysis of the single and three phase fully controlled converter fed series and separately excited D.C motor drives: Continuous and discontinuous conduction mode, control of output voltage by sequence and sector control, harmonic analysis.

UNIT – II: CHOPPER CONTROLLED DC MOTOR DRIVES
Basic equations of motor operation-DC chopper Drives-Basic class A chopper circuit-Analytical properties of the load voltage waveforms-Analytical waveforms of the load current -Average current, r.m.s current and power transfer-Problems.

UNIT – III: STATOR SIDE CONTROL OF INDUCTION MOTOR

UNIT – IV: ROTOR SIDE CONTROL OF INDUCTION MOTOR
Rotor resistance control- fixed resistance control, variable resistance control-converter controlled resistance control, Slip power recovery schemes- Static Kramer drive-Phasor diagram-torque expression-Speed control of Kramer drive-Static scherbius drive-modes of operation.

UNIT – V: VECTOR CONTROL OF INDUCTION MOTOR
Principles of vector control, Direct vector control, derivation of indirect vector control, implementation – block diagram; estimation of flux, flux weakening operation.

TEXT BOOKS


REFERENCE BOOKS

Pre-requisites: Power Systems and Power Electronics

Course Educational Objective: This course enables the student to identify the power quality issues and suitable power conditioners for improvement of power quality.

Course Outcomes:
At the end of the course, student will be able to:
CO1: Differentiate between different types of power quality problems
CO2: Identify the sources of power quality problems
CO3: Analyze the power quality monitoring equipment and power quality standards
CO4: Apply power quality mitigation methods to improve power quality
CO5: Interpret the power quality benchmarking process

UNIT - I: OVERVIEW OF POWER QUALITY
Power quality (PQ) problem, Voltage sag, Swell, Surges, Harmonics, over voltages, spikes, Voltage fluctuations, Transients, interruption overview of power quality phenomenon, Remedies to improve power quality, power quality monitoring.

UNIT - II: VOLTAGE SAGS AND INTERRUPTIONS
Sources of sags and interruptions-Estimating Voltage sag performance-Fundamental principles of protection-Solutions at the End-User level-Evaluating the economics of different ride-through alternatives-Motor- starting sags-Utility system fault-clearing issues.

UNIT - III: HARMONICS

UNIT - IV: POWER QUALITY MONITORING & MITIGATION
Monitoring considerations-Historical perspective of power quality measuring instruments- Power quality measurement equipment-Assessment of power quality measurement data- Application of intelligent systems-Power quality monitoring standards.
Overview of mitigation methods—from fault to trip, reducing the number of faults, reducing the fault clearing time, changing the power system, installing mitigation equipment, improving equipment immunity, different events and mitigation methods.

UNIT - V: POWER QUALITY BENCHMARKING
Introduction, Benchmarking process, power quality contracts, power quality insurance, power quality state estimation, power quality in distribution planning.

Wiring and Grounding: Typical wiring and grounding problems, solutions to wiring and grounding problems in the context of power quality.

TEXT BOOKS:

REFERENCES:
Pre-requisites: Power Electronics and Power Systems

COURSE EDUCATIONAL OBJECTIVES: This course enables the student to analyze various FACTS controllers and mitigating the reactive power.

Course Outcomes: At the end of the course, student will be able to:

CO1. Illustrate the various FACTs controllers
CO2. Analyze series and shunt compensation
CO3. Understand the importance of voltage regulators
CO4. Analyze the concepts of UPFC

UNIT – I: INTRODUCTION

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: SHUNT COMPENSATION

Principles of shunt compensation – Variable Impedance type & switching converter type- Static Synchronous Compensator (STATCOM) configuration, characteristics and control.

UNIT – III : SERIES COMPENSATION

Principles of static series compensation using GCSC, TCSC and TSSC, Static Synchronous Series Compensator (SSSC).

UNIT – IV: VOLTAGE REGULATORS

Principles of operation-Steady state model and characteristics of a static voltage regulators and phase shifters- power circuit configurations.

UNIT – V: UNIFIED POWER FLOW CONTROLLER (UPFC)


TEXT BOOKS


REFERENCE BOOKS

Pre-requisites: Power Electronics

COURSE EDUCATIONAL OBJECTIVES: This course enables the student to illustrate HVDC transmission technologies, their evolution and analysis.

COURSE OUTCOMES: At the end of the course, student will be able to:
CO1. Outline the HVDC technology and conversion principles used in power transmission
CO2. Understand the converters used in HVDC transmission system
CO3: Identify various faults in converter station
CO4: Analyze the concepts of harmonics and filters

UNIT – I: HVDC Basic Concepts


UNIT – II: Converter Theory and Performance

Valve characteristics, converter configuration, analysis of 6-pulse converters and 2-pulse converters, converter transformer rating, Multiple bridge converter, current source converter, Multiterminal D.C (M.T.D.C) systems and types

UNIT – III: Control of HVDC System

Basic principle of control, Hierarchy of controls, control implementation, starting, stopping and power flow reversal, Converter firing controls schemes -Constant α control, Inverse cosine control

UNIT – IV: Converter Faults & Protection


UNIT – V: Harmonics and Filters

A.C and D.C side Harmonics – Characteristic harmonics Non- Characteristic harmonics, adverse effects of harmonics, Types of AC filters, D.C filters.

TEXT BOOKS


REFERENCES


**23PE06-MODERN CONTROL THEORY**

M.Tech. (I Sem.)

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**Prerequisite:** Control systems

**Course Educational Objective:** This course enables the student to learn modern state-space methods to design and analyze continuous-time control systems.

**Course outcomes:**
At the end of the course, student will be able to:
- CO1: Analyze the state-space model of continuous linear and non-linear systems
- CO2: Apply Lyapunov stability theorem to non-linear LTI systems
- CO3: Identify expected state-space trajectories
- CO4: Formulate the optimal control problems

**UNIT – I: MODEL CONTROL**
Introduction to controllability and observability- Effect of state feedback on controllability and observability, Design of State Feedback Control through Pole placement, Full order observer and reduced order observer.

**UNIT – II: DESCRIBING FUNCTION ANALYSIS**
Introduction to Non Linear Systems, behavior of nonlinear systems, properties of Nonlinear Systems, Types of Nonlinearities – Saturation – Dead Zone – Hysteresis-Relay-Backlash etc. Introduction to Linearization of nonlinear systems, Describing function (DF)– Derivation of general DF, DF for different nonlinearities-saturation, Dead-Zone-Dead-Zone and Saturation, Hysteresis-Backlash .Stability analysis of Non – Linear systems through describing functions.

**UNIT – III: PHASE PLANE ANALYSIS**
Introduction to phase plane analysis, singular points, and their classification, limit cycle and behavior of limit cycle- Analytical method, Isoclines method, and delta method for constructing Trajectories, phase plane analysis of nonlinear control systems.

**UNIT – IV: STABILITY ANALYSIS**

**UNIT – V: OPTIMAL CONTROL**

**TEXT BOOKS:**

**REFERENCES:**

M.Tech. (Power Electronics & Electrical Drives) R23 Regulations (w.e.f. 2023-24)
Prerequisites: Electrical Machines

Course Objective: This course enables the student to gain knowledge on modeling and analysis of all rotating machines under dynamic and steady state conditions.

Course Outcomes: At the end of the course, student will be able to:
CO1: Develop models for linear and nonlinear magnetic circuits
CO2: Develop torque equation of an electrical machine using the concepts of field Energy
CO3: Construct machine models based on different reference frames
CO4: Synthesize equivalent circuit parameters for synchronous and asynchronous machines

UNIT – I: BASIC CONCEPTS OF MODELING
Basic Two-pole Machine representation of Commutator machines, 3-phase synchronous machine with and without damper bars and 3-phase induction machine, Kron’s primitive Machine-voltage, current and Torque equations.

UNIT – II: DC MACHINE MODELING

UNIT – III: MODELING OF 1-PHASE INDUCTION MOTOR
Linear transformation-Phase transformation - three phase to two phase transformation (abc to αβ0) and two phase to three phase transformation (αβ0 to abc) --Power equivalence-Modeling of 1-Phase induction motor-cross field theory-mathematical modeling of 1-phase induction motor.

UNIT – IV: MODELING OF THREE PHASE INDUCTION MACHINE

UNIT – V: MODELLING OF SYNCHRONOUS & SPECIAL MACHINES
Synchronous machine inductances – Mathematical model-Transformation to the rotor’s dq0 reference frame- Flux linkages in terms of winding currents-referring rotor quantities to the stator- voltage equations in the rotor’s dq0 reference frame-electromagnetic torque-currents in terms of flux linkages-steady state operation- modelling of PM Synchronous motor, modeling of BLDC motor, modeling of Switched Reluctance motor.

TEXT BOOKS

REFERENCE BOOKS
**Pre-requisites:** Engineering Mathematics

**Course Educational Objective:** This course enables the student to illustrate the fundamental concepts of Optimization Techniques of various classical and Evolutionary methods for constrained and unconstrained problems and their applications in electrical engineering.

**Course Outcomes:** At the end of the course, student will be able to:

CO1: Analyze linear and non-linear optimization problems in electrical engineering

CO2: Apply the concept of optimality criteria for various types of engineering problems

CO3: Apply the dynamic optimization techniques for engineering systems

CO4: Apply the meta-heuristic optimization techniques for engineering systems

**UNIT-I: INTRODUCTION TO OPTIMIZATION**

An overview of optimization problem, concepts and terms related to optimization, necessary and sufficient conditions for a multivariable function, Effects of scaling or adding a constant to an objective function, understanding of constrained and unconstrained optimization problems, properties of convex function and definiteness of a matrix and test for concavity of a function, numerical examples.

**UNIT-II: LINEAR PROGRAMMING**


**UNIT-III: NON-LINEAR PROGRAMMING**


**UNIT-IV: DYNAMIC OPTIMIZATION**

Euler-Lagrange equation, optimal control with constraints on input, Dynamic programming-principle of optimality, concept of time optimal control problem and mathematical formulation of problem, solution of time-optimal control problem, numerical examples, Ripple control in power electronic system using dynamic programming optimization.

**UNIT-V: META HEURISTIC OPTIMIZATION TECHNIQUES**

Genetic Algorithms, Particle Swarm Optimization, Covariance Matrix Adoption Evaluation Strategies, Optimal timing of over current relay control using PSO algorithm.

**TEXT BOOKS**


**REFERENCES**

Pre-requisites: Knowledge in Engineering, English

Course Objective: To understand the research problem, to know the literature studies, plagiarism and ethics, to get the knowledge about technical writing to analyze the nature of intellectual property rights and new developments and research related information and to know the patent rights

Course Outcomes: After the completion of the course, students should be able to

CO1 Analyze the research problem and its formulation.
CO2 Analyze the significance of research ethics
CO3 Apply the information technology for better tomorrow and to develop creativity.
CO4 Identify the importance of intellectual property rights to be promoted among students in general & engineering in particular
CO5 Describe the IPR protection for new and better products, and in turn brings about, economic growth and social benefits.

UNIT I- RESEARCH PROBLEM AND SCOPE FOR SOLUTION
Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

UNIT II- FORMAT
Effective literature studies approaches, analysis, Plagiarism, Research ethics. Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

UNIT III- PROCESS AND DEVELOPMENT

UNIT IV- PATENT RIGHTS

UNIT V- NEW DEVELOPMENTS IN IPR
New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.
TEXT BOOKS
   engineering students”
2. Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”

REFERENCES
   in New Technological Age”, 2016.
Pre-requisites: Power Electronics and Solid State Drives

Course Educational Objective: This course enables the student to get hands on experience on various power semiconductor devices, converter circuits and drives through experimentation.

Course Outcomes: At the end of the course, student will be able to:

CO1: Control DC motor drives using hardware controllers
CO2: Control AC motor drives using hardware controllers
CO3: Examine the characteristics of power electronic devices
CO4: Analyze the performance of different power electronic converters using hardware controllers

LIST OF EXPERIMENTS

Hardware based:
1. Switching characteristics of power diode, BJT, MOSFET, IGBT and SCR using bread board
2. Determination of output voltage and characteristics of 1-phase dual converter with RL load
3. Determination of output voltage and frequency of 1-phase step down cyclo converter with R & RL loads for different firing angles
4. Output voltage characteristics of 3-phase IGBT based PWM Inverter on R & R-L loads for different modulation indices
5. Output voltage characteristics of diode clamped multi-level inverter with R & RL loads
6. Speed control of three phase converter-controlled dc motor drive
7. Study and analyze the performance of four quadrant operation of chopper fed dc motor drive at different firing angles
8. Determination of speed and output voltage of 3-phase A.C. Voltage controller fed induction motor drive
9. Starting and Running characteristics of capacitor start & capacitor run single phase Induction Motor
10. Output voltage characteristics of flying capacitors multi-level inverter-fed induction motor drive

Additional Experiments
11. Speed control of a three-phase slip ring Induction motor by Static Rotor Resistance Control
12. Speed control of a three-phase induction motor drive using vector control method
Pre-requisites: Power Electronics and Solid State Drives
Course Educational Objective: This course enables the student to get hands on experience on various power semiconductor devices, converter circuits and drives using simulation tools.
Course Outcomes: At the end of the course, student will be able to:
CO1: Design various power electronic converters using software
CO2: Simulate various power electronic devices to analyze their performance
CO3: Design and control AC drives using software tools
CO4: Design and control DC drives using software tools

LIST OF EXPERIMENTS
Simulation based:
1. Switching characteristics of power diode, BJT, MOSFET, IGBT and SCR
2. Output voltage and current characteristics of 1-phase step down cyclo converter with R & RL loads for different firing angles
3. Output voltage and current characteristics of 3-phase IGBT based PWM Inverter on R & R-L loads
4. Output voltage and current characteristics of diode clamped multi-level inverter with R & RL loads using PWM technique
5. Speed control of three phase converter-controlled dc motor drive using PWM technique
6. Starting and Running characteristics of capacitor start & capacitor run single phase induction motor using PWM control technique
7. Torque and speed characteristics of four quadrant chopper fed dc motor drive
8. Determination of speed and output voltage of 3-phase A.C. Voltage controller fed induction motor drive using PWM technique
9. Speed control of 3 phase Induction motor with SPWM and SVPWM techniques
10. Output voltage and current characteristics of flying capacitors multi-level inverter fed to induction motor drive using PWM technique

Additional Experiments
11. Torque and speed control of 3 phase slip ring Induction motor by Static Rotor Resistance Control using control switches
12. Torque and speed control of three phase induction motor drive using v/f control technique
Pre-requisites : Power Electronics
Course Educational Objective: This course enables the student to understand principles and basic topologies of switched mode power converters.

Course Outcomes: At the end of the course, student will be able to:
CO1: Identify various types of switched mode converter topologies
CO2: Analyze various DC-DC converter topologies
CO3: Illustrate soft switching techniques
CO4: Analyze different types of power factor correction circuits

UNIT-I: NON ISOLATED SWITCHMODE POWER CONVERTERS
Analysis & Designing of Buck converters, Boost converters, Buck-Boost converters, Cuk converters-continuous and discontinuous modes, applications, problems.

UNIT-II: ISOLATED SWITCHMODE POWER CONVERTERS

UNIT -III: SOFT SWITCHING CONVERTERS
Classification of Resonant Converters-Basic resonant circuits- Series resonant circuit-Parallel resonant circuits- Resonant switches, Concept of Zero voltage switching-Principle of operation, analysis of M-type and L-type Buck or boost Converters-Concept of Zero current switching-Principle of operation-Analysis of M-type and L-type Buck or boost Converters.

UNIT- IV: POWER FACTOR CORRECTION CIRCUITS
Introduction, Definition of PF and THD, Power Factor Correction, Energy Balance in PFC Circuits, Passive Power Factor Corrector, Basic Circuit Topologies of Active Power Factor Correctors, System Configurations of PFC Power Supply, CCM Shaping Technique, Current Mode Control, Voltage Mode Control, Other PFC Techniques.

UNIT- V: CONTROL METHODS FOR SWITCHING POWER CONVERTERS
Control methods for buck, boost and forward dc-dc converters using State-space Modelling, Converter Transfer Functions, Pulse Width Modulator Transfer Functions, and Linear Feedback Design Ensuring Stability.

TEXT BOOKS:

REFERENCES:
Pre-requisites: Power Electronics and Solid State Drives

Course Educational Objective: This course enables the student to illustrate the operation of electric drives controlled from a power electronic converter and to introduce the design concepts of controllers. It also deals with the steady state operation and transient dynamics of a motor-load system.

Course Outcomes: At the end of the course, student will be able to:

- CO1: Analyze DTC & sensor less vector controls of induction motor
- CO2: Control synchronous motor drive with different controlling strategies
- CO3: Control SRM drive with different controlling strategies
- CO4: Analyze the controlling of BLDC and Linear motors with different controlling strategies

UNIT – I: DTC & SENSORLESS VECTOR CONTROL OF INDUCTION MOTOR

UNIT – II: CONTROL OF SYNCHRONOUS MOTOR DRIVES
Synchronous motor and its characteristics- Control strategies-Constant torque angle control power factor control, constant flux control, flux weakening operation, Load commutated inverter fed synchronous motor drive, motoring and regeneration, phasor diagrams.

UNIT – III: CONTROL OF SWITCHED RELUCTANCE MOTOR DRIVES
SRM-principle of operation, Design aspects of stator and rotor pole arcs, torque equation, torque-speed characteristics-Stator Excitation-techniques of sensor less operation-convertor topologies- SRM Waveforms-SRM drive design factors-Torque controlled SRM-Torque Ripple- Instantaneous Torque control -using current controllers-flux controllers.

UNIT – IV: CONTROL OF BLDC MOTOR DRIVES

UNIT – V: CONTROL OF LINEAR MOTORS
Types of linear motors, construction details-Flat LIMs, Tubular LIMs, LIM equivalent circuit, Design considerations, applications of LIM. Control of Linear induction motor-Linear synchronous motor (LSM), Principle of operation, Types of LSM, Iron core LSM and Air core LSM, Control of LSM, soft starters

TEXT BOOKS

REFERENCE BOOKS
23PE11-ARTIFICIAL INTELLIGENCE
TECHNIQUES & ITS APPLICATIONS

M.Tech. (II Sem.)

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Pre-requisites: Control Systems

Course Educational Objective: This course enables the student to understand the basic principles of soft computing techniques, problem solving paradigms of ANN, fuzzy, genetic algorithms, particle Swarm Optimization & Meta-heuristics and their applications to electrical engineering.

Course Outcomes: At the end of the course, student will be able to:
CO1: Interpret different types of neural network models
CO2: Enumerate different types of fuzzification and defuzzification methods
CO3: Analyze GA, PSO and meta-heuristic techniques
CO4: Apply AI techniques to solve various engineering problems

UNIT-I: ARTIFICIAL NEURAL NETWORKS

UNIT-II: FUZZY LOGIC
Introduction to classical and fuzzy sets, crisp sets, universal sets, properties of crisp sets, partition and covering, operations on crisp sets, crisp relations, operations on relations, fuzzy sets - membership function, properties of fuzzy sets, basic fuzzy set operations, fuzzy relations, operations on fuzzy relations, cardinality and relative of fuzzy relations, Fuzzification, development of rule based system, fuzzy propositions, fuzzy operators, fuzzy quantifiers, fuzzy inference, fuzzy decision making system, fuzzy ranking, defuzzification to crisp sets, defuzzification methods, control of phase controlled dc motor drive by using fuzzy logic controllers.

UNIT III: GENETIC ALGORITHM

UNIT IV: PARTICLE SWARM OPTIMIZATION
PSO algorithm, parameter selection, Neighborhoods and topologies, Inner workings- Convergence, Biases, Variants- Hybridization, Alleviate premature, Simplifications, Multi-objective optimization, Binary, discrete, and combinatorial, PSO applications to power converter systems.

UNIT V: META-HEURISTICS TECHNIQUES

TEXT BOOKS
REFERENCES

10. Susana Estefany De, Hugo Calleja, Jesus Aquayo Alquicira, “Metaheuristic optimization methods applied to power converters:A review”, IEEE transaction on power electronics, volume 30, issue 12, December 2015.
Pre-requisites: Power Electronics

Course Educational Objective: This course enables the student to illustrate the advanced concepts of typical power electronic circuits, their topologies and control.

Course Outcomes: At the end of the course, student will be able to:
CO1: Illustrate various switching techniques
CO2: Analyze the operation of different dc-dc and dc-ac converters
CO3: Understand the operation of matrix converters
CO4: Analyze various sources of harmonics and its mitigation

Unit-I: SWITCHING TECHNIQUES

Unit-II: DC – DC CONVERTERS

Unit-III: ADVANCES IN INVERTERS

Unit-IV: MATRIX CONVERTER

Unit-V: HARMONIC MITIGATIONS

Text Books:

Reference Books:


23PE13-MICRO AND SMART GRID TECHNOLOGIES

M.Tech. (II. Sem.)

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**Prerequisite:** Power systems

**Course Educational Objective:** This course enables the student to illustrate micro & smart grid technologies and their significance in power systems.

**Course Outcomes:** At the end of the course the student will be able to:

CO1: Illustrate the features of micro & smart grids
CO2: Analyze power quality problems in an electricity network
CO3: Apply the concept of distributed generation for integration with the existing power system network
CO4: Identify suitable active power controllers in power system network

**UNIT-I: MICRO GRIDS**
Concept and definition of microgrid, microgrid drivers and benefits, review of sources of microgrids, typical structure and configuration of a microgrid, AC and DC microgrids, Power Electronic interfaces in DC and AC microgrids, communication infrastructure, modes of operation and control of microgrid: grid connected and islanded mode, Active and reactive power control, protection issues, anti-islanding schemes: passive, active and communication-based techniques

**UNIT-II: POWER QUALITY ISSUES IN MICROGRIDS**
Introduction to Power quality issues in microgrids - Modelling and Stability analysis of Microgrid, regulatory standards, Microgrid economics, Introduction to smart microgrids.

**UNIT - III: INTRODUCTION TO SMART GRID**
Review of power system operation and control, Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid, Concept of Resilient & Self-Healing Grid, Present development & International policies in Smart Grid. Case study of Smart Grid. CDM opportunities in Smart Grid.

**UNIT- IV: SMART GRID COMMUNICATIONS AND MEASUREMENT TECHNOLOGY**

**UNIT V-RENEWABLE ENERGY AND STORAGE**
Renewable Energy Resources - Sustainable Energy Options for the Smart Grid - Penetration and Variability Issues associated with Sustainable Energy Technologies - Demand Response Issues-Electric Vehicles and Plug - in Hybrid Technologies - Environmental Implications - Storage Technologies - Grid integration issues of renewable energy sources

**TEXT BOOKS:**

**REFERENCE BOOKS:**
Pre-requisites: Control systems, Power Electronics and Drives

Course Educational Objective: This course enables the student to illustrate the characteristics, architecture, control and management strategies of hybrid electric vehicles.

Course Outcomes: At the end of the course, student will be able to:
- CO1: Explore fundamental concepts of hybrid electric vehicles
- CO2: Analyze the performance of electric and hybrid electric vehicles
- CO3: Illustrate different energy management strategies for hybrid electric vehicles
- CO4: Control various drives used in hybrid electric vehicles

UNIT – I: INTRODUCTION
History of hybrid electric vehicles, social and environmental importance of hybrid electric vehicles, impact of modern drive-trains on energy supplies. Conventional Vehicles- Basics of vehicle performance, vehicle power source characterization, transmission characteristics and mathematical models to describe vehicle performance.

UNIT – II: HYBRID ELECTRIC DRIVE-TRAIN
Electric Drive-trains: Basic concepts of electric traction, introduction to various electric drives-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis. Basic concepts of hybrid traction- introduction to various hybrid drives-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis.

UNIT – III: ELECTRIC PROPULSION
Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, Switched Reluctance Motor drives, drive system efficiency.

UNIT – IV: DRIVE SYSTEM
Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor and power electronics, selecting the energy storage technology, Communications, supporting subsystems.

UNIT – V: ENERGY MANAGEMENT STRATEGIES
Introduction, classification and comparison of different energy management strategies, implementation issues of energy management strategies.
Case Studies: Design of Hybrid Electric Vehicle (HEV), Battery Electric Vehicle (BEV).

TEXT BOOKS:

REFERENCES:
2. Chris MI, M. Abul and David Wenzhong Gao, “Hybrid Electrical Vehicle Principles and Application with Practical Perspectives”.
Prerequisites: Electrical Machines and Power Electronics

Course Objective: This course enables the student to gain knowledge on various wind energy conversion systems and converter topologies for extracting power from wind systems.

Course Outcomes: At the end of the course, student will be able to:
CO1: Illustrate basic components of wind energy system
CO2: Analyse wind turbine technologies
CO3: Understand the operation of wind energy conversion systems
CO4: Analyse modelling and controlling of DFIG

UNIT - I: Introduction

Unit II: Wind Turbines Technology-I
Wind turbines types: Vertical Axis Type, Horizontal Axis, Constant Speed Constant Frequency, Variable speed Variable Frequency, Up Wind, Down Wind, Stall Control, Pitch Control, Gear Coupled Generator type, Direct Generator Drive /PMG/Rotor Excited Sync Generator Wind Turbine Technology & Components of WTG - Gear Coupled Generator Type for Const. Speed- Direct Coupled Generator Type [Variable Speed Variable Frequency]: Multipole Synchronous / PMG Generators.

Unit III: Wind Turbines Technology-II

UNIT - IV: Wind Energy Conversion Systems
Overview of Wind Energy Conversion Systems (WECS), Wind Turbine Technologies, classifications of WECS, performance of induction generators for WECS, self-excited induction generator for isolated power generators, capacitance requirements, power conditioning schemes, Maximum Power Point Tracking (MPPT) Control, Synchronous Generators

UNIT - V: Modeling, Operation and Control of DFIG

TEST BOOKS:

REFERENCES:
4. Ramesh & Kumar “Renewable Energy Technologies”, Narosa publishers
Prerequisite: -Nil-

Course Educational Objective: This course enables the student to learn various sources of EMI, digital circuit noises, filtering and shielding mechanisms.

Course outcomes: At the end of the course, student will be able to:
CO1: Analyze various sources of EMI and noises
CO2: Illustrate different methods of hardening
CO3: Analyze filtering and shielding mechanisms
CO4: Illustrate electrostatic discharge and its standards

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

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

UNIT- III.: BALANCING, FILTERING AND SHIELDING

UNIT-IV.: DIGITAL CIRCUIT NOISE AND LAYOUT
Frequency versus time domain- analogy versus digital circuits- digital logic noise- internal noise sources- digital circuit ground noise –power distribution-noise voltage objectives measuring noise voltages-unused inputs-logic families

UNIT-V.: ELECTROSTATIC DISCHARGE & STANDARDS

TEXT BOOKS

REFERENCE BOOKS
23PE63-Power Converters and Drives-II Lab

M.Tech. (II Sem.)

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Pre-requisites: Power Electronics and Solid State Drives

Course Educational Objective: This course enables the student to get hands on experience in understanding power converter circuits and advanced electric drives through experimentation.

Course Outcomes: At the end of the course, student will be able to

- **CO1**: Analyze the performance of various power converters
- **CO2**: Control the speed of PMSM and BLDC motors using digital controllers
- **CO3**: Control the speed of SRM and 3-phase induction motors using digital controllers
- **CO4**: Develop code for different applications using digital controllers

LIST OF EXPERIMENTS

Hardware based:

1. DC output voltage & AC link voltage characteristics of isolated dc-dc resonant converter
2. Output voltage characteristics of dc-dc buck converter with R & RL loads using FPGA controller
3. Power factor correction of PIC Microcontroller based boost converter
4. Output voltage and current characteristics of dc-dc buck boost converter with R & RL loads
5. Output voltage and current characteristics of dc-dc forward converter with R & RL loads
6. Speed control of PM synchronous motor by voltage control method
7. Speed control of BLDC motor by voltage control method
8. Speed control of Switched Reluctance Motor with eddy current loads
9. Speed control of 3 phase Induction motor with DSP based V/f technique
10. Digital to Analog converter (DAC) and Analog to Digital converter (ADC) using digital controller

Additional Experiments

11. Generation of sinusoidal signal using digital controller
12. Generation of three phase sine triangle PWM pulses using digital controller
Pre-requisites: Power Electronics and Solid state Drives

Course Educational Objective: This course enables the student to get hands on experience in understanding power converters and advanced electric drives through simulation tools.

Course Outcomes: At the end of the course, student will be able to:
   CO1: Analyze the performance of various power converters using simulation tools
   CO2: Control the speed of PMSM and BLDC motors using simulation tools
   CO3: Control the speed of SRM and 3-phase induction motors using simulation tools

LIST OF EXPERIMENTS

Simulation based:
1. Power factor correction boost converter using PWM technique
2. Load voltage & current characteristics of isolated dc-dc resonant converter using PWM technique
3. Load voltage & current characteristics of dc-dc buck converter using PWM and pulse delay control techniques
4. Load & source voltage and current characteristics of dc-dc buck boost converter with R & RL loads using hysteresis PWM control technique
5. Load voltage & current characteristics of dc-dc forward converter with R & RL loads using hysteresis PWM control technique
6. Load voltage & current characteristics of dc-dc cuk converter with R & RL loads using PWM control technique
7. Load voltage & current characteristics of dc-dc fly back converter with R & RL loads using hysteresis PWM control technique
8. Speed control of PM synchronous motor by voltage control method
9. Speed control of BLDC motor by voltage control method
10. Speed control of switched reluctance motor using PWM control technique

Additional Experiments
1. Load voltage & current characteristics of push-pull dc-dc converter with R & RL loads using PWM control technique
2. Load voltage & current characteristics of full bridge dc-dc converter with R & RL loads using PWM control technique
Pre-requisites: Microprocessors and Microcontrollers and Elements of Signal Processing

Course Educational Objective: This course enables the student understander architecture of digital signal processors & FPGA controllers and their programming for real time industrial applications.

COURSE OUTCOMES: At the end of the course, student will be able to:

CO1: Interpret the architectural features of digital signal processor

CO2: Analyze the addressing modes of C2xx DSP processor

CO3: Control converters using DSP processors

CO4: Analyze FPGA controller and control various power converters

UNIT – I: INTRODUCTION TO DSP
Introduction, Digital signal-processing system, the sampling process, Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT), Basic Architectural features of DSP processor TMS323LF2407, Memory Mapping.

UNIT – II: I/O & EVENT MANAGERS
Pin Multiplexing (MUX) and General Purpose I/O Overview, Peripheral interrupt expansion unit. Overview of the Event manager (EV), Compare Units, Capture Units and Quadrature Encoder Pulse (QEP) Circuit.

UNIT - III: DSP PROGRAMMING
Memory Addressing modes- Immediate addressing mode- Direct addressing mode and Indirect addressing modes. C2xx DSP CPU and Instruction Set-using assembly instruction set, Introduction to the C2xx DSP Core and Code Generation- the Components of the C2xx DSP Core -Mapping External Devices to the C2xx Core and the Peripheral Interface.

UNIT - IV: DSP-BASED IMPLEMENTATION TO POWER CONVERTERS
Introduction - Converter Structure - Continuous Conduction Mode-Discontinuous Conduction Modes of Buck, Boost converters-Connecting and controlling Buck and Boost Converters through DSP controller.

UNIT - V: FPGA-BASED SYSTEMS & APPLICATIONS
Introduction, Digital design and FPGAs-The role of FPGA, FPGA types and FPGA Vs Custom VLSI, FPGA based system design-Goals and techniques, Hierarchical design, design abstraction and methodologies, FPGA Architecture.

APPLICATIONS:
Design examples using PLDs, FPGA fabrication – logic elements, interconnect, FPGA generic design flow, FPGA partitioning, placement and routing, gate pulse generation using FPGA.

TEXT BOOKS:
2. Wayne Wolf," FPGA based system design ", Prentice hall, 2004
REFERENCES:
3. TMS323LF2407 datasheets (Texas Instruments)
Pre-requisites: Microprocessors & Microcontrollers

Course Educational Objective: This course enables the student to illustrate the structure and instructions of advanced microprocessors like-8086/8088/80386/80486/Pentium, microcontrollers like-8051/PIC micro controllers and their interfacing for various power electronic applications.

Course Outcomes: At the end of the course, student will be able to:

CO1: Analyze the architecture of various microprocessors
CO2: Analyze the architecture of various microcontrollers
CO3: Develop the assembly language programs for various power electronic applications
CO4: Interface various peripheral devices to processors/controllers

UNIT-I: ADVANCED PROCESSORS

Review of 8086 microprocessor, Architecture, register organization, Pin diagram, instruction set, addressing modes of 80386, 486 and Pentium Processors their memory management, Introduction to Pentium Pro Processors their features, RISC Vs CISC Processors.

UNIT-II: BASIC PERIPHERALS & THEIR INTERFACING

Memory Interfacing (DRAM), PPI- Modes of operation of 8255, interfacing to ADC, DAC, Programmable timer- 8253, PIC 8259A, Display controller, Programmable Communication Interface 8251-USART and their interfacing.

UNIT-III: MICRO CONTROLLERS

Introduction to Intel 8-bit and 16-bit Micro controllers, 8051-Architecture, memory organization, addressing modes, Instruction formats, Instruction sets, Interrupt structure and interrupt priorities, Port structures, and Operation Linear Counter functions, Different modes of operation and programming examples.

UNIT-IV: OVERVIEW OF PIC MICROCONTROLLERS

Introduction to PIC micro controllers -Advantage of PIC micro controllers – Types and products of PIC. Applications- LCD, LED and 7 Segment Interfacing with different peripheral devices -Different types of display units.

UNIT- V: APPLICATIONS

Based on microprocessors-Sine, triangular and square wave generations, control of step- up and step- down choppers. Control of buck, boost and buck-boost converters through 8051/PIC microcontroller.

TEXT BOOKS:

REFERENCES:
M.Tech. (III Sem)

Pre-requisites: Electronic Circuits & Devices and Power Electronics

Course Educational Objective: This course enables the student to understand switching characteristics, design of gate drive and protection circuits for various power semiconductor devices.

Course Outcomes: At the end of the course, student will be able to:
CO1: Analyze switching characteristics of different power semiconductor devices
CO2: Illustrate various protection circuits
CO3: Develop gate driver circuits for power semiconductor devices
CO4: Understand different passive components and noise sources

UNIT-I: BJTS & MOSFETS

BJTs: Introduction- vertical power transistor structures-I-V characteristics-physics of BJT operation
switching characteristics-break down voltages-second break down-on-state losses-safe operation areas
design of drive circuits for BJTs-snubber circuits for BJTs and Darlington’s

MOSFETs: Introduction- basic structures-I-V characteristics-physics of device operation-switching
characteristics-operation limitations and safe operating areas-design of gate drive circuits, snubber circuits.

UNIT-II: IGBTs & IGCTs

IGBTs: Introduction-basic structures-I-V characteristics-physics of device operation-Latch in IGBTs
switching characteristics-Device limits and safe operating areas-drive and snubber circuits.

IGCTs: Introduction-basic structures-I-V characteristics-physics of device operation-Integrated Gate
Commutated Thyristors (IGCTs) switching characteristics-Device limits and safe operating areas-drive and
snubber circuits.

UNIT-III: EMERGING DEVICES AND CIRCUITS

Introduction-basic structures-I-V characteristics-physics of device operation-GTO switching
characteristics-snubber circuits-over protection of GTOs-Power junction field effect transistors-field
controlled Thyristor-JFET based devices versus other power devices-MOS controlled Thyristors-high
voltage integrated circuits-new semiconductor materials

UNIT-IV: PASSIVE COMPONENTS, ELECTROMAGNETIC COMPATIBILITY AND NOISE

Introduction-design of inductor-transformer design-selection of capacitors-resistors current measurements-
heat sinking circuit lay out –Electromagnetic Interference (EMI)-Sources of EMI-Electromagnetic
generated due to switching-Common noises sources in SMPS-Noise due to high frequency transformer-conducted noise measurement - minimizing EMI-EMI shielding-EMI standards.

UNIT-V: PROTECTION OF DEVICES & CIRCUITS


TEXT BOOK:

Reference books
Pre-requisites: Nil

Course Educational Objectives:
- To enable the student to understand the importance of constitution.
- To understand the structure of Executive, Legislature and Judiciary.
- To understand Philosophy of fundamental rights and duties.
- To understand the autonomous nature of constitution bodies like Supreme Court and High Court Controller and Auditor General of India and Election Commission of India.
- To understand the Central and State relation, financial and administrative.

Course Outcomes: At the end of the course, the student shall be able to
CO1: Understand history and philosophy of constitution with reference to Preamble, Fundamental Rights and Duties (Understand – L2).
CO2: Understand the concept of Unitary and Federal Government along with the role of President, Prime Minister and Judicial System (Understand – L2).
CO3: Understand the structure of the state government, Secretariat, Governor and Chief Minister and their functions (Understand – L2).
CO4: Learn local administration viz. Panchayat, Block, Municipality and Corporation (Understand – L2).
CO5: Learn about Election Commission and the process and about SC, ST, OBC and women (Understand – L2).

UNIT – I:

UNIT – II:
Union Government and its Administration Structure of the Indian Union: Federalism Centre – State relationship, President: Role, Power and Position. Prime Minister (PM) and Council of Ministers, Cabinet and Central Secretariat, Lok Sabha, Rajya Sabha. The Supreme Court and High Court: Powers and Functions.

UNIT – III:
State Government and its Administration Governor – Role and Position – Chief Minister (CM) and Council of Ministers. State Secretariat: Organization, Structure and Functions.

UNIT – IV:
A Local Administration -- Role and Importance, Municipalities – Mayor and Role of Elected Representative, Panchayati Raj: Functions of Panchayati Raj Institution, Zilla Panchayat, Elected Officials and their roles, Village level – Role of Elected and Appointed officials.

UNIT – V:

Reference Books:
3. J. A. Siwach, Dynamics of Indian Government and Politics.

E-Resources:
1. nptel.ac.in/courses/109104074/8.
2. nptel.ac.in/courses/109104045.
3. nptel.ac.in/courses/101104065.
Pre-Requisites: Knowledge in English

Course Educational Objective:
This course gives knowledge on research paper writing skills. This course also describes the different sections of the research paper. This course also provides skills that are needed for publication which includes paper preparation, plagiarism check and submission process.

Course Outcomes (COs): At the end of the course, students will be able to
CO1: Understand research article readability and writing skills.
CO2: Identify essential parameters of each section of research articles.
CO3: Apply the knowledge for writing and submit research paper for publication.
CO4: Develop skills that are required to maintain quality of research paper.

UNIT-I: Research paper Writing Skills Part-I
Planning and Preparation, Word Order, Breaking up long sentences, Structuring, Paragraphs and Sentences, Being Concise, and Removing Redundancy

UNIT-II: Research paper Writing Skills Part-II
Avoiding Ambiguity and Vagueness, Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticising, Paraphrasing and Plagiarism

UNIT-III: Parts of research Paper
Title, Abstract, Introduction, Review of the Literature, Methods, Results, Discussion, Conclusions, the Final Check.

UNIT-IV: Preparation of manuscript
Key skills are needed when writing a Title, an Abstract, an Introduction, a Review of the Literature, the Methods, the Results, the Discussion, Conclusions, preparing the tables and figures

UNIT-V: Publishing the Paper
Rights and Permission, How to Submit the Manuscript, The Review Process (How to Deal with Editors), The Publishing Process (How to Deal with Proofs) and After Publication.

Text Books:
Prerequisite: Basic Electrical and Electronics Engineering

Course Educational Objective: This course enables the student to study the characteristics of power semiconductor devices and to familiarize the principle of operation & performance of various power electronic converters.

Course Outcomes: At the end of the course, the student will be able to:

CO1: Understand the characteristics of various power semiconductor devices.

CO2: Analyze the operating principles for single-phase and three phase thyristor based rectifiers

CO3: Analyze operation of dc-dc converters in steady state in continuous and discontinuous modes

CO4: Interpret the operation of ac voltage controllers and cyclo converters

CO5: Understand the operation and performance of inverters

UNIT – I: POWER SEMI-CONDUCTOR DEVICES
Power semiconductor switches–Characteristics of SCR–Two transistor model- Static and dynamic characteristics–Turn on and Turn off methods-Series and Parallel operation of thyristors-Gate triggering circuits-Characteristics of GTO & IGBT.

UNIT – II: PHASE-CONTROLLED RECTIFIERS
Single phase and three phase- Half wave, Full wave and bridge controlled rectifiers with R and RL loads–continuous and discontinuous modes-effect of freewheeling diode-Dual converters (both single phase and three phase).

UNIT – III: AC VOLTAGE CONTROLLERS & CYCLO CONVERTERS
AC voltage controllers–single phase ac voltage controller with R and RL loads– continuous and discontinuous modes- Principle of operation of Cyclo-converter -Single phase to single phase cyclo converters -Step up and step-down Cyclo converters.

UNIT – IV: DC TO DC CONVERTERS

UNIT – V: INVERTERS
Single phase inverter–Voltage Source Inverter (VSI)-Current source inverters (CSI) - Comparison between VSI and CSI- Analysis with R & RL loads-3-phase inverters–180 and 120degree modes of operation.

TEXT BOOKS:

REFERENCE:
Prerequisite:

Course Educational Objective: This course presents the various sources of renewable energy such as solar, wind, geothermal energy, biomass & other potential energy and contribution towards energy profile of the nation.

Course Outcomes: At the end of the course, the student will be able to:

- CO2: Illustrate the components of wind energy systems.
- CO3: Illustrate the working of biomass, digesters and Geothermal plants.
- CO4: Demonstrate the principle of Energy production from OTEC, Tidal and Waves.
- CO5: Evaluate the concept and working of Fuel cells & MHD power generation

UNIT–I Solar Energy:

UNIT–II Wind Energy:
Introduction - basic Principles of Wind Energy Conversion, the nature of Wind - the power in the wind - Wind Energy Conversion - Site selection considerations - basic components of Wind Energy Conversion Systems (WECS) - Classification - Applications.

UNIT–III Biomass and Geothermal Energy:

UNIT–IV Energy From oceans, Waves & Tides: Oceans:


Text Books:

Reference Books:
Pre-requisite course: Basic Electrical and Electronics Engineering

COURSE OBJECTIVES: This course enables the student to introduce the need of energy auditing and devise energy efficient control strategies. It also deals with active power management, energy efficient lighting schemes and energy conservation methods.

COURSE OUTCOMES: At the end of the course, the student will be able to:
CO1: Illustrate the different parameters for energy auditing
CO2: Interpret the controlling of energy management and energy efficiency
CO3: Analyze the Reactive power management strategies.
CO4: Analyze energy conservation measures for economic aspects.

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, building energy audit. Smart Metering, Energy saving through smart metering. Energy conservation in vehicles, energy conservation in buildings

UNIT-II: ENERGY MANAGEMENT
Principles of energy management, organizing energy management program, initiating, planning, controlling, promoting, monitoring, reporting- Energy manger, Qualities and functions, language.

UNIT-III: ENERGY EFFICIENT MOTORS
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, power factor with non linear loads, effect of harmonics on power factor, power factor motor controllers - Good lighting system design and practice, lighting control, lighting energy audit - Energy Instruments- wattmeter, 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.

TEXT BOOKS:

REFERENCE:
3. Energy management and good lighting practice: fuel efficiency booklet12 – EEO.