# DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

## COURSE STRUCTURE & SYLLABUS for

## M.Tech EEE Common for Power Electronics (PE) Programme

*(Applicable for batches admitted from 2019-2020*

## PRAKASAM ENGINEERING COLLEGE

### (Autonomous)
### Affiliated to JNTUK
### KANDUKUR –523105, Andhra Pradesh, India

# PRAKASAM ENGINEERING COLLEGE
## (Autonomous)
## Affiliated to JNTUK
## KANDUKUR –523105, Andhra Pradesh, India

## COURSE STRUCTURE - PE

| S.No | Course No | Category | Course Name | P.Os | L | T | P | C | Marks |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | PC | Electrical Machine Modeling and Analysis | | 3 | 0 | 0 | 3 | 100 |
| 2 | | PC | Analysis of Power Electronic Converters | | 3 | 0 | 0 | 3 | 100 |
| 3 | | PE | Elective – I<br>  i. Modern Control Theory<br>  ii. Power Quality and Custom Power Devices<br>  iii. Programmable Logic Controllers & Applications | | 3 | 0 | 0 | 3 | 100 |
| 4 | | PE | Elective – II<br>  i. Artificial Intelligence Techniques<br>  ii. Renewable Energy Technologies<br>  iii. HVDC Transmission and Flexible AC Transmission Systems | | 3 | 0 | 0 | 3 | 100 |
| 5 | | | Research Methodology and IPR | | 2 | 0 | 0 | 2 | 100 |
| 6 | | | Power Electronics Simulation Laboratory | | 0 | 0 | 4 | 2 | 100 |
| 7 | | | Power Converters Laboratory | | 0 | 0 | 4 | 2 | 100 |
| 8 | | | Audit Course – 1 | | 2 | 0 | 0 | 0 | 100 |
| | | | | | 16 | 0 | 8 | 18 | 800 |

**II Semester**

| S.No | Course No | Category | Course Name | P.Os | L | T | P | C | Marks |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | PC | Switched Mode Power Conversion | | 3 | 0 | 0 | 3 | 100 |
| 2 | | PC | Power Electronic Control of Electrical Drives | | 3 | 0 | 0 | 3 | 100 |
| 3 | | PE | Elective – III<br>  i. Control & Integration of Renewable Energy Systems<br>  ii. Hybrid Electric Vehicles<br>  iii. Digital Control Systems | | 3 | 0 | 0 | 3 | 100 |
| 4 | | PE | Elective – IV<br>  i. Advanced Digital Signal Processing<br>  ii. Applications of Power Converters<br>  iii. Microcontrollers | | 3 | 0 | 0 | 3 | 100 |
| 5 | | | Electric Drives Simulation Laboratory | | 0 | 0 | 4 | 2 | 100 |
| 6 | | | Electric Drives Laboratory | | 0 | 0 | 4 | 2 | 100 |
| 7 | | | Mini Project with Seminar | | 0 | 0 | 4 | 2 | 100 |
| 8 | | | Audit Course – 2 | | 2 | 0 | 0 | 0 | 100 |
| | | | | | 14 | 0 | 12 | 18 | 800 |

**Audit course 1 & 2**
1. English for Research Paper Writing
2. Disaster Management
3. Sanskrit for Technical Knowledge
4. Value Education
5. Constitution of India
6. Pedagogy Studies
7. Stress Management by Yoga
8. Personality Development through Life Enlightenment Skills.

| I- Semester | **Electrical Machines Modeling and Analysis** | **Category** | **L-T-P** 3-0-0 | **Credits** 3 |
|---|---|---|---|---|

**Pre-requisite:** Electrical machines & Special machines.

**Course Educational Objectives:**

- To know the concepts of generalized theory of electrical machines.
- To represent the DC and AC machines as Basic Two Pole machine.
- To model the electrical machines with voltage, current, torque and speed equations.
- To investigate the steady state and transient behavior of the electrical machines.
- To understand the dynamic behavior of the AC machines.

## UNIT– 1
### Basic concepts of Modeling
Basic two-pole machine representation of Commutator machines, representations of 3-phase synchronous machine with and without damper bars and 3-phase induction machine, Kron"s primitive Machine voltage, current and torque equations.

## UNIT– 2
### DC Machine Modeling
Mathematical model of separately excited D.C motor – Steady state analysis-transient State analysis-sudden application of inertia load-transfer function of separately excited D.C motor- Mathematical model of D.C Series motor, Shunt motor-Linearization techniques for small perturbations

## UNIT– 3
### Reference frame theory & Modeling of single phase Induction Machines
Linear transformation-Phase transformation - three phase to two phase transformation (abc to $\alpha\beta0$) and vice-versa, transformation to rotating reference frame, ($\alpha\beta0$ to dqo) and vice versa -Power equivalence-Mathematical modeling of single phase induction machines.

## UNIT– 4
### Modeling of three phase Induction Machine
Generalized model in arbitrary reference frame-Derivation of commonly used induction machine models-Synchronously rotating reference frame model, Stator reference frame model-Rotor reference frame model--power equation, electromagnetic torque equation, state space model in induction motor with flux linkages as variables

## UNIT– 5
### Modeling of Synchronous Machine
Synchronous machine inductances –derivation of voltage equations in the rotor"s dq0 reference frame electromagnetic torque-current in terms of flux linkages-three phase synchronous motor. State space models with flux linkages as variables.

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

- Analyze the characteristics of different types of DC motors to design suitable controllers for different applications.
- Apply the knowledge of reference frame theory for AC machines to model the induction and Synchronous machines.
- Evaluate the steady state and transient behavior of induction and synchronous machines to propose the suitability of drives for different industrial applications
- Analyze the behavior of induction machines using voltage and torque equations.

**Text Books**
1. Analysis of Electric Machinery and Drive Systems, 3rd Edition-Wiley-IEEE Press- Paul Krause, Oleg Wasynczuk, Scott D. Sudhoff, Steven Pekarek, Junr 2013.
2. Electric Motor Drives - Modeling, Analysis& control -R.Krishnan- Pearson Publications.

**Reference Books**:
1. Generalized theory of Electrical Machines -Fifth edition, Khanna Publishers P. S. Bimbhra, 1985.
2. Dynamic simulation of Electric machinery using MATLAB / Simulink –CheeMunOng- Prentice Hall, 2003.
3. Magneto electric devices transducers, transformers and machines-G. R. Slemon- Wiley in New York, London, 1966.

| I-Semester | Analysis of Power Electronic Converters | Category | L-T-P 3-0-0 | Credits 3 |
|---|---|---|---|---|

**Pre-Requisite:** Power Electronics.

**Course Educational Objectives:**
- To understand the control principle of ac to ac conversion with suitable power semi - conductor devices.
- To have the knowledge of ac to dc conversion and different ac to dc converter topologies.
- To understand the effect of operation of controlled rectifiers on p.f. and improvement of p.f. with PFC converters
- To acquire the knowledge on dc-ac converters and to know the different control techniques of dc-ac converters.
- To know multilevel inverter configuration to improve the quality of the inverter output voltage.

**UNIT– 1**
**Overview of Switching Devices:**
Power MOSFET, IGBT, GTO, GaN devices-static and dynamic characteristics, gate drive circuits for switching devices.

**UNIT– 2**
**AC-DC converters:** Single phase fully controlled converters with RL load– Evaluation of input power factor and harmonic factor- Continuous and Discontinuous load current, Power factor improvements, Extinction angle control, symmetrical angle control, PWM control. Three Phase AC-DC Converters, fully controlled converters feeding RL load with continuous and discontinuous load current, Evaluation of input power factor and harmonic factor-three phase dual converters.

**UNIT– 3**
**Power Factor Correction Converters:** Single-phase single stage boost power factor corrected rectifier, power circuit principle of operation, and steady state- analysis, three phase boost PFC converter

**UNIT– 4**
**PWM Inverters:** Principle of operation-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- $60^0$PWM- Third Harmonic PWM- Space Vector Modulation- Comparison of PWM Techniques- Three phase current source inverters-Variable dc link inverter.

**UNIT– 5**
**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- Principle of Operation, Features of Flying-Capacitors Inverter- Cascaded Multilevel Inverter- Principle of Operation- Features of Cascaded Inverter-Switching Device Currents-DC-Link Capacitor Voltage Balancing- Features of Multilevel Inverters-Comparisons of Multilevel Converters.

**Course Outcomes**: At the end of the course, student will be able to
- Describe and analyze the operation of AC-DC converters.
- Analyze the operation of power factor correction converters.
- Analyze the operation of three phase inverters with PWM control.
- Study the principles of operation of multi- level inverters and their applications.

**Text Books**

1. Power Electronics: Converters, Applications, and Design- Ned Mohan, Tore M. Undeland, William P. Robbins, John Wiley& Sons, 2nd Edition, 2003.
2. Power Electronics-Md.H.Rashid –Pearson Education Third Edition- First IndianReprint-2008.

**Reference Books**:

1. Power Electronics Daniel W. Hart - McGraw-Hill, 2011.
2. Elements of Power Electronics – Philip T. Krein, Oxford University press, 2014.
3. Power Converter Circuits – William Shepherd & Li Zhang-Yes Dee CRC Press, 2004.

| I-Semester | **Modern Control Theory** **(Elective-I)** | Category | **L-T-P** **3-0-0** | **Credits** **3** |
|---|---|---|---|---|

**Pre-requisite:**Control Systems, differential equations.

**Course Educational Objectives:**

- To facilitate the evolution of state variable approach for the analysis of control systems.
- To examine the importance of controllability and observability in modern control engineering.
- To enable students to analyze various types of nonlinearities & construction of trajectories using describing functions and phase plane analysis.
- To study the analysis of stability and instability of continuous time invariant system.

**UNIT– 1**

**State Variable Analysis**

The concept of state – State Equations for Dynamic systems– Solution of Linear Time Invariant Continuous-Time State Equations, State transition matrix and it"s properties. Controllability and Observability of state model in Jordan Canonical form - Controllability and Observability Canonical forms of State model

**UNIT– 2**

**Design using state variable technique**

Design of state feedback controller through pole placement technique-Necessary and sufficient condition-Ackermann"s formula. Concept of observer-Design of full order state observer-reduced order observer.

**UNIT– 3**

**Non Linear Systems**

Classification of Nonlinearities- common physical nonlinearities– Characteristics of nonlinear systems - Singular Points –Linearization of nonlinear systems– Describing function – describing function analysis of nonlinear systems- Stability analysis of Nonlinear systems through describing functions.

**UNIT– 4**

**Stability Analysis**

Stability in the sense of Lyapunov, Lyapunov"s stability and Lyapunov"s instability theorems – Stability Analysis of Linear Continuous time invariant systems by Lyapunov method – Generation of Lyapunov functions – Variable gradient method – Krasooviski"s method.

**UNIT– 5**

**Introduction to Optimal Control**

Minimization of functional of single function – Constrained minimization – Minimum principle – Control variable inequality constraints – Control and state variable inequality constraints – Euler Lagrangine equation.

Typical optimal control performance measures-optimal control based on Quadratic performance measures- Quadratic optimal regulator systems- State regulator problems –Output regulator problems, tracking problems; Riccati equation-Infinite time regulator problem-Reduce matrix Riccati equation-determination of optimal feedback gain matrix.

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

- Formulate and solve the state equations of dynamic systems, analyze controllability and observability.
- Design a state feedback controller; design an observer.
- Linearize a nonlinear system model; analyze non-linear systems through describing functions.
- Determine the stability of a given system; generate a Lyapunov function.
- Minimize a given functional, design an optimal feedback gain matrix.

**Text Books:**
1. Modern Control Engineering – by K. Ogata, Prentice Hall of India, 3rd edition, 1998.
2. Automatic Control Systems by B.C. Kuo, Prentice Hall Publication.

**Reference Books:**
1. Modern Control System Theory – by M. Gopal, New Age International Publishers, 2nd edition,1996
2. Control Systems Engineering by I.J. Nagarath and M.Gopal, New Age International (P) Ltd.
3. Digital Control and State Variable Methods – by M. Gopal, Tata McGraw–Hill Companies, 1997.
4. Systems and Control by Stainslaw H. Zak , Oxford Press, 2003.
5. Optimal control theory: an Introduction by Donald E.Kirk by Dover publications.
6. Modern control systems, Richard C. Dorf and Robert H. Bishop, 11th Edition, Pearson Edu, India, 2009

| I-Semester | **Power Quality and Custom Power Devices (Elective-I)** | **Category** | **L-T-P 3-0-0** | **Credits 3** |
|---|---|---|---|---|

**Pre requisite:** Knowledge on electric circuit analysis, power systems and power electronics and concept of reactive power compensation techniques.

**Course Educational Objectives:**

- To understand significance of power quality and power quality parameters.
- To know types of transient over voltages and protection of transient voltages.
- To understand harmonics, their effects, harmonic indices and harmonic minimization techniques.
- To understand the importance of power devices and their applications.
- To understand different compensation techniques to minimize power quality disturbances.

**UNIT– 1**

**Introduction to power quality:** Overview of Power Quality, Concern about the Power Quality, General Classes of Power Quality Problems, Voltage Unbalance, Waveform Distortion, Voltage fluctuation, Power Frequency Variations, Power Quality Terms, Voltage Sags, swells, flicker and Interruptions - Sources of voltage and current interruptions, Nonlinear loads.

**UNIT– 2**

**Transient and Long Duration Voltage Variations:** Source of Transient Over Voltages - Principles of Over Voltage Protection, Devices for Over Voltage Protection, Utility Capacitor Switching Transients, Utility Lightning Protection, Load Switching Transient Problems.

Principles of Regulating the Voltage, Device for Voltage Regulation, Utility Voltage Regulator Application, Capacitor for Voltage Regulation, End-user Capacitor Application, Regulating Utility Voltage with Distributed generation

**UNIT– 3**

**Harmonic Distortion and solutions:** Voltage vs. Current Distortion, Harmonics vs. Transients - Power System Quantities under Non-sinusoidal Conditions, Harmonic Indices, Sources of harmonics, Locating Sources of Harmonics, System Response Characteristics, Effects of Harmonic Distortion, Inter harmonics, Harmonic Solutions Harmonic Distortion Evaluation, Devices for Controlling Harmonic Distortion, Harmonic Filter Design, Standards on Harmonics

**UNIT– 4**

**Custom Power Devices:** Custom power and custom power devices, voltage source inverters, reactive power and harmonic compensation devices, compensation of voltage interruptions and current interruptions, static series and shunt compensators, compensation in distribution systems, interaction with distribution equipment, installation considerations.

**UNIT– 5**

**Application of custom power devices in power systems:** Static and hybrid Source Transfer Switches, Solid state current limiter - Solid state breaker. P-Q theory – Control of P and Q, Dynamic Voltage Restorer (DVR): Operation and control – Interline Power Flow Controller (IPFC): Operation and control of Unified Power Quality Conditioner (UPQC); Generalized power quality conditioner

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

- Identify the issues related to power quality in power systems.
- Address the problems of transient and long duration voltage variations in power systems.
- Analyze the effects of harmonics and study of different mitigation techniques.
- Identify the importance of custom power devices and their applications.
- Acquire knowledge on different compensation techniques to minimize power quality disturbances.

**Text Books**:
1. Electrical Power Systems Quality, Dugan R C, McGranaghan M F, Santoso S, and Beaty H W, Second Edition, McGraw-Hill, 2002.
2. Understanding Power Quality Problems: Voltage Sags and Interruptions, Bollen M H J, First Edition, IEEE Press; 2000.
3. Guidebook on Custom Power Devices, Technical Report, Published by EPRI, Nov 2000
4. Power Quality Enhancement Using Custom Power Devices – Power Electronics and Power Systems, Gerard Ledwich, ArindamGhosh, Kluwer Academic Publishers, 2002.

**Reference Books**:
1. Power Quality Primer, Kennedy B W, First Edition, McGraw-Hill, 2000.
2. Power System Harmonics, Arrillaga J and Watson N R, Second Edition, John Wiley & Sons, 2003.
3. Electric Power Quality control Techniques, W. E. Kazibwe and M. H. Sendaula, Van Nostrad Reinhold, New York.
4. Power Quality c.shankaran, CRC Press, 2001
5. Harmonics and Power Systems –Franciso C.DE LA Rosa-CRC Press (Taylor & Francis).
6. Power Quality in Power systems and Electrical Machines-EwaldF.fuchs, Mohammad A.S. Masoum-Elsevier
7. Power Quality, C. Shankaran, CRC Press, 2001
8. Instantaneous Power Theory and Application to Power Conditioning, H. Akagiet.al., IEEE Press, 2007.
9. Custom Power Devices - An Introduction, ArindamGhosh and Gerard Ledwich, Springer, 2002
10. A Review of Compensating Type Custom Power Devices for Power Quality Improvement, Yash Pal et.al., Joint International Conference on Power System Technology and IEEE Power India Conference, 2008. POWERCON 2008.

| I-Semester | **Programmable Logic Controllers & Applications (Elective-I)** | Category | **L-T-P** 3-0-0 | **Credits** 3 |
|---|---|---|---|---|

**Pre-requisite:**Knowledge on relay logic and digital electronics.

## Course Educational Objectives:

- To have knowledge on PLC.
- To acquire the knowledge on programming of PLC.
- To understand different PLC registers and their description.
- To have knowledge on data handling functions of PLC.
- To know how to handle analog signal and converting of A/D in PLC.

**UNIT– 1**
**PLC Basics:**
PLC system, I/O modules and interfacing, CPU processor, programming equipment, programming formats, construction of PLC ladder diagrams, devices connected to I/O modules.

**UNIT– 2**
**PLC Programming:**
Input instructions, outputs, operational procedures, programming examples using contacts and coils. Drill press operation. Digital logic gates, programming in the Boolean algebra system, conversion examples. Ladder diagrams for process control: Ladder diagrams and sequence listings, ladder diagram construction and flow chart for spray process system.

**UNIT– 3**
**PLC Registers:**
Characteristics of Registers, module addressing, holding registers, input registers, output registers. PLC Functions: Timer functions and Industrial applications, counters, counter function industrial applications, Arithmetic functions, Number comparison functions, number conversion functions.

**UNIT– 4**
**Data Handling functions:**
SKIP, Master control Relay, Jump, Move, FIFO, FAL, ONS, CLR and Sweep functions and their applications. Bit Pattern and changing a bit shift register, sequence functions and applications, controlling of two axis and three axis Robots with PLC, Matrix functions.

**UNIT– 5**
**Analog PLC operation:**
Analog modules and systems, Analog signal processing, multi bit data processing, analog output application examples, PID principles, position indicator with PID control, PID modules, PID tuning, PID functions.

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

- Understand the PLCs and their I/O modules.
- Develop control algorithms to PLC using ladder logic etc.
- Manage PLC registers for effective utilization in different applications.
- Handle data functions and control of two axis and their axis robots with PLC.
- Design PID controller with PLC.

**Text Books:**

1. Programmable Logic Controllers – Principle and Applications by John W. Webb and Ronald A. Reiss, Fifth Edition, PHI
2. Programmable Logic Controllers – Programming Method and Applications by JR. Hackworth and F.D Hackworth Jr. – Pearson, 2004.

**Reference Books:**

1. Introduction to Programmable Logic Controllers- Gary Dunning-Cengage Learning.
Programmable Logic Controllers –W.Bolton-Elsevier publisher.

| I-Semester | Artificial Intelligence Techniques (Elective-II) | Category | L-T-P 3-0-0 | Credits 3 |
|---|---|---|---|---|

**Pre –requisite:** Fundamentals of Neural networks and Fuzzy Logic

**Course Educational Objectives:**

- To have knowledge on concept of neural network.
- To know different types of neural networks and training algorithms.
- To understand the concept of genetic algorithm and its application in optimization.
- To have the knowledge on fuzzy logic and design of fuzzy logic controllers.
- To know the applications of AI Techniques in electrical engineering.

**UNIT– 1**
**Introduction**
Artificial Neural Networks (ANN) – definition and fundamental concepts – Biological neural networks – Artificial neuron – activation functions – setting of weights – typical architectures – biases and thresholds – learning/training laws and algorithms. Perceptron – architectures, ADALINE and MADLINE – linear separability- XOR function.
**UNIT– 2**
**ANN Paradigms**
ADALINE – feed forward networks – Back Propagation algorithm- number of hidden layers – gradient decent algorithm – Radial Basis Function (RBF) network. Kohonen''sself organizing map (SOM), Learning Vector Quantization (LVQ) and its types – Functional Link Networks (FLN) – Bidirectional Associative Memory (BAM) – Hopfield Neural Network.
**UNIT– 3**
**Classical and Fuzzy Sets**
Introduction to classical sets- properties, Operations and relations; Fuzzy sets, Membership, Operations, Properties, Fuzzy relations, Cardinalities, Membership functions.
**UNIT– 4**
**FUZZY LOGIC CONTROLLER (FLC)**
Fuzzy logic system components: Fuzzification, Inference engine (development of rule base and decision making system), Defuzzification to crisp sets- Defuzzification methods.
**UNIT– 5**
**Application of AI Techniques**
Speed control of DC motors using fuzzy logic –load flow studies using back propagation algorithm, single area and two area load frequency control using fuzzy logic.

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

- Differentiate between Algorithmic based methods and knowledge based methods.
- Use appropriate AI framework for solving power system problems.
- To design fuzzy logic controllers for power engineering applications.

**Text Books:**

1. Introduction to Artificial Neural Systems - Jacek M. Zuarda, Jaico Publishing House, 1997.
2. Fuzzy logic with Fuzzy Applications – T.J Ross – McGraw Hill Inc, 1997.

**Reference Books:**

1. Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications by S.Rajasekaran andG.A.VijayalakshmiPai – PHI Publication.
2. Modern power Electronics and AC Drives – B.K.Bose -Prentice Hall, 2002
3. Genetic Algorithms- David E Goldberg. Pearson publications.
5. Introduction to Neural Networks using MATLAB 6.0 by S N Sivanandam,SSumathi,S N Deepa TMGH
6. Introduction to Fuzzy Logic using MATLAB by S N Sivanandam,SSumathi,S N Deepa Springer, 2007.

| I-Semester | Renewable Energy Technologies (Elective-II) | Category | L-T-P 3-0-0 | Credits 3 |
|---|---|---|---|---|

**Pre requisite:** UG power Electronics.

**Course Educational Objectives:**

- To learn technical challenges in renewable energy.
- To learn basics of wind energy conversion & PV power generation.
- To analyze  the of fuel cell system.

**UNIT– 1**
**Introduction:** Renewable Sources of Energy; Distributed Generation; Renewable Energy Economics - Calculation of Electricity Generation Costs; Demand-Side Management Options; Supply-Side Management Options; Control of renewable energy based power Systems

**UNIT– 2**
**Induction Generators:** Principles of Operation; Representation of Steady-State Operation; Power and Losses Generated - Self-Excited Induction Generator; Magnetizing Curves and Self-Excitation - Mathematical Description of the Self-Excitation Process; Interconnected and Stand-alone operation - Speed and Voltage Control.

**UNIT– 3**
**Wind Power Plants:** Site Selection; Evaluation of Wind Intensity; Topography; Purpose of the Energy Generation- General Classification of Wind Turbines; Rotor Turbines; Multiple-Blade Turbines; Drag Turbines; Lifting Turbines - Generators and Speed Control Used in Wind Power Energy; Analysis of Small wind energy conversion system.

**UNIT– 4**
**Photovoltaic Power Plants:** Solar Energy; Generation of Electricity by Photovoltaic Effect; Dependence of a PV Cell on Temperature and irradiance input-output Characteristics - Equivalent Models and Parameters for Photovoltaic Panels; MPPT schemes: P&O,INC, effect of partial shaded condition. Applications of Photovoltaic Solar Energy-Economical Analysis of Solar Energy

**UNIT– 5**
**Fuel Cells:** The Fuel Cell; Low- and High-Temperature Fuel Cells; Commercial and Manufacturing Issues - Constructional Features of Proton Exchange-Membrane Fuel Cells; Reformers; Electrolyzer Systems; Advantages and Disadvantages of Fuel Cells - Fuel Cell Equivalent Circuit; Practical Determination of the Equivalent Model Parameters; Aspects of Hydrogen for storage

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

- Understand various general aspects of renewable energy systems.
- Analyze and design induction generator for power generation from wind.
- Design MPPT controller for solar power utilization.
- Utilize fuel cell systems for power generation.

**Text Books:**

1. Felix A. Farret, M. Godoy Simo` es, Integration of Alternative Sources of Energy, John Wiley & Sons, 2006.
2. Remus Teodorescu, Marco Liserre, Pedro Rodríguez, Grid Converters for Photovoltaic and Wind Power Systems, John Wiley & Sons, 2011.

**Reference Books:**

1. Gilbert M. Masters, Renewable and Efficient Electric Power Systems, John Wiley & Sons, 2004

| I-Semester | **HVDC Transmission and Flexible AC Transmission Systems (Elective-II)** | **Category** | **L-T-P 3-0-0** | **Credits 3** |
|---|---|---|---|---|

**Pre-requisite:**Knowledge on Power Electronics, Power Systems and High Voltage Engineering

**Course Educational Objectives:**

- To learn various schemes of HVDC transmission.
- To learn the operation and analysis of different HVDC converter circuits.
- To learn the control of HVDC systems.
- To learn the basic types of FACTS controllers.
- To learn the series and shunt compensators.

**UNIT– 1**
**HVDC Transmission:** DC Power Transmission: Need for power system interconnections, Evolution of AC and DC transmission systems, Comparison of HVDC and HVAC Transmission systems, Types of DC links, relative merits, Components of a HVDC system, Modern trends in DC Transmission systems

**UNIT– 2**
**Analysis of HVDC Converters:** Pulse number, choice of converter configurations, Analysis of Graetz circuit with and without overlap, voltage waveforms, Analysis of two and three valve conduction mode, Converter Bridge characteristics, Inverter mode of operation, voltage waveforms

**UNIT– 3**
**HVDC Control:** Principles of DC link control, Converter Control characteristics, Control hierarchy Constant current Control, CEA Control, firing angle control of valves, starting and stopping of a dc link, Power control

**Harmonics and Filters:** effects of Harmonics, sources of harmonic generation, Types of filters –Design examples

**UNIT– 4**
**Power Flow Analysis in AC/DC Systems:** Modelling of DC links, solutions of AC-DC Power flow
**Flexible AC Transmission Systems (FACTS):** FACTS concepts and general system conditions: Power flow in AC systems, Relative importance of controllable parameters, Basic types of FACTS controllers, shunt and series controllers, Current source and Voltage source converters

**UNIT– 5**
**Static Shunt Compensators:** Objectives of shunt compensation, Methods of controllable VAR generation, Static Var Compensator, its characteristics, TCR, TSC, STATCOM, basic operating principle, control approaches and characteristics

**Static Series Compensators:** Objectives of series compensator, variable impedance type of series compensators, TCSC, TSSC-operating principles and control schemes, SSSC, Power Angle characteristics, Control range and VAR rating, Capability to provide reactive power compensation, external control

Introduction to Unified Power Flow Controller, Basic operating principles, Conventional control capabilities, Independent control of real and reactive power.

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

- Compare HVDC and EHVAC transmission systems
- Analyze converter configurations used in HVDC and evaluate the performance metrics.
- Understand controllers for controlling the power flow through a dc link and compute filter Parameters.
- Apply impedance, phase angle and voltage control for real and reactive power flow in ac transmission systems with FACTS controller.
- Analyze and select a suitable FACTS controller for a given power flow condition.

**Text Books**:

1. NarainG.Honorani, Laszlo Gyugyi: Understanding FACTS –Concepts and Technology of Flexible AC Transmission Systems, Wiley-IEEE Press, 2000.
2. K.R.Padiyar: HVDC Power Transmission Systems –Technology and System Interactions, New Age International Publishers, 2011.

**Reference Books**:

1. Kimbark: Direct Current Transmission, 1971.
2. Jos Arrillaga: High Voltage Direct Current Transmission, The Institution of electrical Engineers, 1998.
3. Yong Hua Song, Allan T Johns: Flexible AC Transmission Systems, The Institution of electrical Engineers, 1999.

| I-Semester | Research Methodology and IPR | Category | L-T-P 2-0-0 | Credits 2 |
|---|---|---|---|---|

## UNIT-I

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

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

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

## UNIT-IV

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

## UNIT-V

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.

**REFERENCES:**

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students""
2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
3. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"
4. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.
5. Mayall, "Industrial Design", McGraw Hill, 1992.

| I-Semester | **POWER ELECTRONICS SIMULATION LABORATORY** | **CATEGORY** | **L-T-P** 0 -0-4 | **CREDITS** 2 |
|---|---|---|---|---|

**Course Educational Objectives:**
To analyze the operation of DC-DC converters, AC-DC converters and DC-AC converters by simulation.

**Any 10 of the following experiments are to be conducted.**

**List of Experiments:**
1. Simulation of Buck converter using small signal model.
2. Simulation of Boost converter using small signal model.
3. Simulation of single phase half bridge inverter.
4. Simulation of single-phase full bridge inverter using Uni-polar & Bi-polar PWM techniques.
5. Simulation of three phase inverter using sine-triangle PWM.
6. Simulation of three phase inverter using space vector PWM.
7. Simulation of three level three phase NPC inverter.
8. Study of neutral point voltage floating in NPC three level inverter
9. Simulation of 3-level flying capacitor inverter & evaluation of capacitor voltage balanced methods.
10. Simulation of single phase AC voltage regulator.
11. Simulation of three phase AC voltage regulator.
12. Comparison of harmonic profile of two level& three level inverter (FFT analysis).
13. Simulation of 5-level inverter using carrier based PWM methods.
14. Simulation of three phase full converter with RL & RLE loads.
15. Simulation of three-phase dual converter.

**Course Outcome:** To understand the operation of DC-DC converters, AC-DC converters, AC voltage regulators and DC-AC converters by simulation.

| I-Semester | POWER CONVERTERS LABORATORY | CATEGORY | L-T-P 0 -0-4 | CREDITS 2 |
|------------|----------------------------|----------|--------------|-----------|

**Course Educational Objectives:**
To study and understand the different converters and inverters for single and three phase loads.

**Any 10 of the following experiments are to be conducted.**

**List of experiments**

1. Study of DC-DC non-isolated converters such as Buck & Boost converter.
2. Study of DC-DC Buck-Boost and Cuk converters.
3. Study of 1-$\phi$ dual converter.
4. Determination of input p.f. and harmonic factor for 1-$\phi$semi- converter and 1-$\phi$ full-converter (Inductive load)
5. Study of p.f. improvement in 1-$\phi$ full-converter with symmetric and extinction angle control.
6. Study of 1-$\phi$ square wave and sinusoidal PWM inverter.
7. Study of 3-$\phi$ inverter with 120º and 180º mode of operation.
8. Study of 3-$\phi$ sinusoidal PWM inverter.
9. Study of 3-level NPC inverter.
10. Study of 5-level cascaded H-bridge inverter.
11. Determination of input p.f. and harmonic factor for 3-$\phi$ full converter (Inductive load).
12. Determination of input p.f. and harmonic factor for 3-$\phi$ semi converter (Inductive load).
13. Study the characteristics of IGBT, MOSFET & GTO‟s.
14. Design of gate drive circuits for IGBT & MOSFET‟s.

**Course Outcomes:** Students are able to implement the converter and inverters in real time applications.

| I-Semester | Audit Course-1 | PC | L-T-P 2-0-0 | Credits 0 |
|---|---|---|---|---|

| II-Semester | Switched Mode Power Conversion | Category | L-T-P 3-0-0 | Credits 3 |
|---|---|---|---|---|

**Pre-requisite:**Concepts of electrical circuit analysis and power electronics.

**Course Educational Objectives:**
- To understand the control operation of non-sinusoidal DC-DC converters.
- To understand the basic operation of resonant converters.
- To understand the control operation of isolated DC-DC converters.
- To understand the control schemes of DC-DC converters and designing of magnetic components.
- To understand the modeling and control design of switch mode conversion based on linearization.
- To understand how to analyze the switch mode converters using small-signal analysis.

**UNIT– 1**
**Non-isolated switch mode converters:**
Control of DC-DC converters: Buck converters, Boost converters, Buck-Boost converter, CUK Converter, continuous and discontinuous operation, Converter realization with non-ideal components.
**UNIT– 2**
**Isolated switched mode converters:**
Forwarded converter, flyback converter, push-pull converter, half-bridge converter, full bridge converter.
**UNIT– 3**
**Resonant converters:**
Basic resonant circuit concepts, series resonant circuits, parallel resonant circuits, zero current switching quasi-resonant buck converter, zero current switching quasi-resonant boost converter, zero voltage switching quasi-resonant buck converter, zero voltage switching quasi-resonant boost converter.
**UNIT– 4**
**Control schemes of switching converters:**
Voltage control, Current mode control, control scheme for resonant converters.
Magnetic design consideration: Transformer design, inductor and capacitor design.
**UNIT– 5**
**Modeling and Controller design based on linearization:**
Formulation of averaged models for buck and boost converters:state space analysis, average circuit models, linearization and small – signal analysis, small-signal models.
Control design based on linearization: Transfer function of converters, control design, large signal issues in voltage-mode and current-mode control.

**Course Outcomes**: At the end of the course, student will be able to
- Analyze operation and control of non-isolated and isolated switch mode converters.
- Design of non-isolated and isolated switch mode converters.
- Analyze operation and control of resonant converters.
- Feedback design of switch mode converters based on linearized models.

**Text Books**:
1. Fundamentals of Power Electronics-Erickson, Robert W., Maksimovic, Dragan, Springer, 2011.
2. Power switching converters-Simon Ang, Alejandro Oliva, CRC Press, 2010.
3. Elements of Power Electronics – Philip T. Krein, Oxford University press, 2014.
4. Design of Magnetic Components for Switched Mode Power Converters- Umanand, S.P. Bhat, John Wiley & Sons Australia, 1992.

**Reference Books**:
1. Power Electronics: Essentials and applications- L. Umanand, Wiley publications
2. Switching Power Supply Design-Abraham I. Pressman, McGraw-Hill Ryerson, Limited, 1991.
3. Power Electronics – IssaBatareseh, Jhon Wiley publications, 2004.
4. Power Electronics: converters Applications & Design – Mohan, Undeland, Robbins-Wiley publications.

| II-Semester | Power Electronic Control of Electrical Drives | Category | L-T-P 3-0-0 | Credits 3 |
|---|---|---|---|---|

**Pre-requisite:**Knowledge of Power Electronics and Electrical Machines.

**Course Educational Objectives:**
- To familiarize with advanced control schemes for induction motor drives and control techniques for PMSM, BLDC and SRM drives.

**UNIT– 1**
**Vector Control of Induction Motor Drive:**
Principle of scalar and vector control, direct vector control, indirect vector control, rotor flux oriented control, stator flux oriented control, air gap flux oriented control, decoupling circuits.

**UNIT– 2**
**Sensor less Control of induction Motor Drive:**
Advantages of speed sensor less control, voltage current based speed sensor less control, MRAS-model reference adaptive systems, Extended Kalman filter observers.

**UNIT– 3**
**Direct Torque Control of Induction Motor Drive:**
Principle of Direct torque control (DTC), concept of space vectors, DTC control strategy of induction motor, comparison between vector control and DTC, applications, space vector modulation based DTC of induction motors.

**UNIT– 4**
**Control of Permanent Magnet Synchronous Machines (PMSM) and Brushless DC (BLDC) Motor Drives:**
Advantages and limitations of Permanent magnet machines, operating principle of PMSM,modeling of PMSM, operating principle of BLDC, modeling of BLDC, similarities and difference between PMSM and BLDC, need for position sensing in BLDC motors, control strategies for PMSM and BLDC, methods of reducing torque ripples of BLDC motor.

**UNIT– 5**
**Control of Switched Reluctance Motor (SRM) Drive:**
SRM structure, Merits and limitations, stator excitation, converter topologies, SRM waveforms, Torque control schemes, speed control of SRM, torque ripple minimization, instantaneous -torque control using current controllers and flux controllers.

**Course Outcomes**: After the completion of the course, student will be able to
- Understand the concepts of scalar and vector control methods for drive systems.
- Analyze and design controllers and converters for induction motor, PMSM and BLDC drives.
- Select and implement proper control techniques for induction motor and PMSM for specific applications.
- Analyze and design control techniques and converters for SRM drives.

**Text Books**:
1. Bose B. K., "Power Electronics and Variable Frequency Drives",IEEE Press, Standard Publisher Distributors. 2001.
2. Krishnan R., "Electric Motor Drives – Modeling, Analysis and Control", Prentice Hall of India Private Limited.

**Reference Books**:
1. Switched Reluctance Motors and Their Control-T. J. E. Miller, Magna Physics, 1993.
2. Power electronic converters applications and design-Mohan, Undeland, Robbins-Wiley publications

| II-Semester | **Control & Integration of Renewable Energy Systems (Elective -III)** | **Category** | **L-T-P 3-0-0** | **Credits 3** |
|---|---|---|---|---|

**Pre-requisite:**Power Electronics

**Course Educational Objectives:**
- To understand different conventional & non-conventional dynamic energy conversion technologies.
- To learn the principles of static energy conversion technologies.
- To understand the basics of real & reactive power control with renewable generators.
- To learn the principles of standalone and grid connected systems.

**UNIT-1**
**Introduction:** Electric grid introduction, Supply guarantee and power quality, Stability, Effects of renewable energy penetration into the grid, Boundaries of the actual grid configuration, Consumption models and patterns, static and dynamic energy conversion technologies, interfacing requirements .

**UNIT-2**
**Dynamic Energy Conversion Technologies:** Introduction to different conventional and nonconventional dynamic generation technologies, principle of operation and analysis of reciprocating engines, gas and micro turbines, hydro and wind based generation technologies, control and integrated operation of different dynamic energy conversion devices.

**UNIT-3**
**Static Energy Conversion Technologies:** Introduction to different conventional and nonconventional static generation technologies, principle of operation and analysis of fuel cell, photovoltaic based generators, and wind based generation technologies, different storage technologies such as batteries, fly wheels and ultra-capacitors, plug-in-hybrid vehicles, control and integrated operation of different static energy conversion devices.

**UNIT-4**
**Real and reactive power control:** Control issues and challenges in Diesel, PV, wind and fuel cell based generators, PLL, Modulation Techniques, Dimensioning of filters, Linear and nonlinear controllers, predictive controllers and adaptive controllers, Fault-ride through Capabilities, Load frequency and Voltage Control .

**UNIT-5**
**Integration of different Energy Conversion Technologies:**Resources evaluation and needs, Dimensioning integration systems, Optimized integrated systems, Interfacing requirements, integrated Control of different resources, Distributed versus Centralized Control, Synchro Converters, Grid connected and Islanding Operations, stability and protection issues, load sharing, Cases studies

**Course Outcomes:** After the completion of the course, student will be able to
- Gain knowledge on different renewable energy sources and storage devices
- Recognize, model and simulate different renewable energy sources
- Analyze, model and simulate basic control strategies required for grid connection
- Implement a complete system for standalone/grid connected system

**Text books:**
1. Ali Keyhani Mohammad Marwali and Min Dai, "Integration and Control of Renewable Energy in Electric Power System" John Wiley publishing company
2. S. Chowdhury, S. P. Chowdhury, P. Crossley, "Microgrids and Active Distribution Networks", IET Power Electronics Series, 2012
3. G. Masters, "Renewable and Efficient Electric Power Systems", IEEE-Wiley Publishers, 2013

**References:**
1. Quing-Chang Zhong, "Control of Power Inverters in Renewable Energy and Smart Grid Integration", Wiley, IEEE Press
2. Bin Wu, Yongqiang Lang, NavidZargari, "Power Conversion and Control of Wind Energy Systems", Wiley 2011.

| II-Semester | Hybrid Electric Vehicles (Elective-III) | Category | L-T-P 3-0-0 | Credits 3 |
|---|---|---|---|---|

**Pre-requisite:**Knowledge of Power Electronics and Electric Drives

## Course Educational Objectives:

- To learn the concept of hybrid vehicles, types of electric drives used in hybrid vehicles and their control.

### UNIT– 1
**Introduction:**
History of hybrid vehicles, architectures of HEVs, series and parallel HEVs, complex HEVs.
### UNIT– 2
**Hybridization of Automobile:**
Fundamentals of vehicle, components of conventional vehicle and propulsion load; Drive cycles and drive terrain; Concept of electric vehicle and hybrid electric vehicle; Plug-in hybrid vehicle, constituents of PHEV, comparison of HEV and PHEV; Fuel Cell vehicles and its constituents.
### UNIT– 3
**Plug-in Hybrid Electric Vehicle:**
PHEVs and EREVs blended PHEVs, PHEV Architectures, equivalent electric range of blended PHEVs; Fuel economy of PHEVs, power management of PHEVs, end-of-life battery for electric power grid support, vehicle to grid technology, PHEV battery charging.
### UNIT– 4
**Power Electronics in HEVs:**
Rectifiers used in HEVs, voltage ripples; Buck converter used in HEVs, non-isolated bidirectional DC-DC converter, regenerative braking, voltage source inverter, current source inverter, isolated bidirectional DC-DC converter, PWM rectifier in HEVs, EV and PHEV battery chargers.
### UNIT– 5
**Battery and Storage Systems**
Energy Storage Parameters; Lead–Acid Batteries; Ultra capacitors; Flywheels - Superconducting Magnetic Storage System; Pumped Hydroelectric Energy Storage; Compressed Air Energy Storage - Storage Heat; Energy Storage as an Economic Resource

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

- Know the concept of electric vehicles and hybrid electric vehicles.
- Familiar with different motors used for hybrid electric vehicles.
- Understand the power converters used in hybrid electric vehicles
- Know different batteries and other energy storage systems.

**Text Books**
1. Ali Emadi, Advanced Electric Drive Vehicles, CRC Press, 2014.
2. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.

**Reference Books:**
1. MehrdadEhsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.
2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.
3. H. Partab: Modern Electric Traction – Dhanpat Rai & Co, 2007.

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

| II-SEMESTER | DIGITAL CONTROL SYSTEMS (ELECTIVE-III) | CATEGORY | L-T-P 3-0-0 | CREDITS 3 |
|---|---|---|---|---|

**Pre-Requisite:** Control Systems, digital control systems.

**Course Educational objectives**:
- To understand fundamentals of digital circuits and devices using Z-transforms and Inverse Z-Transforms
- To understand the controllability and observability in digital domain
- To understand the stability and controller design in digital domain
- To understand the design an observer
- To understand the solving of a given optimal control problem

## UNIT– 1
### Introduction
Introduction to analog and digital control systems – Advantages of digital systems – Typical examples–Sample and hold devices – Sampling theorem and data reconstruction-Transfer functions and frequency domain characteristics of zero order hold and first order hold. Review of Z–transforms and Inverse Z–transforms- solving differential equations. Mapping between the S–Plane and the Z–Plane – Primary strips and Complementary Strips

## UNIT– 2
### State space analysis and the concepts of Controllability and observability
State Space Representation of discrete time systems – State transition matrix properties and evaluation – Solution of state equations- Discretization of continuous-time state equations –controllability and observability – concepts, conditions and tests, Principle of duality.

## UNIT– 3
### Stability Analysis and Controller Design
Stability criterion – Modified Routh‟s stability criterion and Jury‟s stability test, Lyapunov‟s stability analysis.
Design of state feedback controller through pole placement techniques, Necessary and sufficient conditions, Ackermann‟s formula, controller for deadbeat response, control system with reference input, Design of full order observer-reduced order observer.

## UNIT– 4
### State Observer
Necessary and sufficient condition for state observation-Full order state observer- error dynamics – design of prediction observers- Ackermann‟s formula-effect of the addition of observer on closed loop system-Current observer- minimum order observer observed – state feedback control system with minimum order observer -control system with reference input.

## UNIT– 5
### Quadratic Optimal Control Systems
Quadratic optimal control problems-Solution by minimization method using Lagrange multipliers-Evolution of the minimum performance index – discretize quadratic optimal control –Steady state Riccati equations-Lyapunov approaches to the solution of the Steady state quadratic optimal regulator problem and optimal control problem - Quadratic optimal control of a servo system.

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

- Analyze digital control systems using Z-transforms and Inverse Z-Transforms.
- Evaluate the state transition matrix and solve state equation for discrete model for continuous time systems, investigate the controllability and observability.
- Determine the stability; design state feedback controller.
- Design an observer.
- Solve a given optimal control problem.

**Text Book:**

1. Discrete–Time Control systems – K. Ogata, Pearson Education/PHI, 2nd Edition.
2. B. C. Kuo, "Digital control systems"- Holt Saunder"s International Edition, 1991.

**Reference Books:**

1. M. Gopal: Digital control engineering, New Age Int. Ltd., India, 1998.
2. K. Ogata, "Modern control engineering"- PHI, 1991.

| II-semester | **Advanced Digital Signal Processing** **(Elective-IV)** | **Category** | **L-T-P** **3-0-0** | **Credits** **3** |
|---|---|---|---|---|

**Pre-requisite:** Signals & Systems

**Course Educational Objectives:**

- To understand the various digital filter structures
- To design the FIR and IIR Filters
- To know the importance of FFT algorithm for computation of Discrete Fourier Transform
- To analyze the finite word length effects on various filters
- To learn the concepts of power spectrum estimation of periodic and non-periodic signals

**UNIT– 1**
**Digital Filter Structure:** Block diagram representation-Equivalent Structures-FIR and IIR digital filter Structures All pass Filters-tunable IIR Digital Filters-IIR tapped cascaded Lattice Structures-FIR cascaded Lattice structures-Parallel-Digital Sine-cosine generator-Computational complexity of digital filter structures.

**UNIT– 2**
**Digital filter design:** Preliminary considerations-Bilinear transformation method of IIR filter design-design of lowpass, high pass-band pass, and band stop- IIR digital filters-Spectral transformations of IIR filters, FIR filter design-based on windowed Fourier series- design of FIR digital filters with least –mean-square-error-constrained least-square design of FIR digital filters

**UNIT– 3**
**DSP algorithm implementation:** Computation of the discrete Fourier transform- number representation-arithmetic operations handling of overflow-tunable digital filters-function approximation.

**UNIT– 4**
**Analysis of finite Word length effects:** The quantization process and errors- quantization of fixed -point and floating -point Numbers-Analysis of coefficient quantization effects, Analysis of arithmetic round-off errors, dynamic range scaling-signal- to- noise ratio in low -order IIR filters-low-sensitivity digital filters-Reduction of Product round-off errors using error feedback-Limit cycles in IIR digital filters, Round-off errors in FFT Algorithms.

**UNIT– 5**
**Power Spectrum Estimation:** Estimation of spectra from finite duration observations signals – Non-parametric methods for power spectrum estimation – parametric method for power spectrum estimation, estimation of spectral form-finite duration observation of signals-non-parametric methods for power spectrum estimation-Walsh methods-Blackman & torchy method.

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

- Describe structure of digital filters.
- Design digital filters with different techniques.
- Understand the implementation aspects of signal processing algorithms.
- Know the effect of finite word length in signal processing.
- Analyze different power spectrum estimation techniques.

**Text Books:**

1. Digital signal processing-Sanjit K. Mitra-TMH second edition, 2002.
2. Discrete Time Signal Processing – Alan V.Oppenheim, Ronald W.Shafer - PHI-1996 1$^{st}$ edition-9th reprint

**Reference Books:**

1. Digital Signal Processing and principles, algorithms and Applications – John G.Proakis -PHI –3rd edition-2002.
2. Digital Signal Processing – S.Salivahanan, A.Vallavaraj, C. Gnanapriya – TMH - 2$^{nd}$ reprint-2001
3. Theory and Applications of Digital Signal Proceesing-LourensR. Rebinar&Bernold.
4. Digital Filter Analysis and Design-Auntonian-TMH.

| II-Semester | Applications of Power Converters (Elective-IV) | Category | L-T-P 3-0-0 | Credits 3 |
|---|---|---|---|---|

**Pre-requisites:** Analysis of Power Electronic Converters

**Course Educational Objectives:**
- To understand the inverters for induction heating applications
- To understand the power converters for different industrial applications
- To understand modeling of high voltage power supplies using the power converters for radar and space applications
- To understand modeling of low voltage and high current power supplies using the power converters for microprocessors and computer loads
- To understand the applications of DC-DC converters

**UNIT-1**
**Inverters for Induction Heating:** For induction cooking, induction hardening, melting, and welding applications.
**UNIT-2**
**Power Converters for Lighting, pumping and refrigeration Systems**: Electronic ballast, LED power drivers for indoor and outdoor applications. PFC based grid fed LED drivers, PV / battery fed LED drivers. PV fed power supplies for pumping/refrigeration applications.
**UNIT-3**
**High Voltage Power Supplies** - Power supplies for X-ray applications - power supplies for radar applications - power supplies for space applications.
**UNIT-4**
**Low voltage high current power supplies:** Power converters for modern microprocessor and computer loads
**UNIT-5**
**Bi-directional DC-DC (BDC) converters: E**lectric traction, automotive Electronics and charge/discharge applications, Line Conditioners and Solar Charge Controllers

**Course Outcomes:** At the end of the course, the student will be able to
- Analyze power electronic application requirements.
- Identify suitable power converter from the available configurations.
- Develop improved power converters for any stringent application requirements.
- Improvise the existing control techniques to suit the application. Design of Bi-directional converters for charge/discharge applications

**Text books:**
1. Ali Emadi, A. Nasiri, and S. B. Bekiarov: Uninterruptible Power Supplies and Active Filters, CRC Press, 2005.

2. M. Ehsani, Y. Gao, E. G. Sebastien and A. Emadi: Modern Electric, Hybrid Electric and Fuel Cell Vehicles, 1st Edition,CRC Press, 2004.
**References:**
1. William Ribbens: Understanding Automotive Electronics, Newnes, 2003.

2. Current literature

| II-Semester | Microcontrollers (Elective-IV) | Category | L-T-P 3-0-0 | Credits 3 |
|---|---|---|---|---|

**Pre-requisite:** Basic micro-processors & micro controllers.

**Course Educational Objectives:**
- To learn about microcontrollers architecture.
- To learn about DSP architecture and assembly programming for DSP processors.
- To learn about basics of FPGA controllers.

**UNIT– 1**
**PIC Microcontrollers**
PIC Microcontrollers: Overview and Features, PIC 16C6X/7X, FSR(File Selection Register) [Indirect Data Memory Address Pointer], PIC Reset Actions, PIC Oscillator Connections, PIC Memory Organizations, PIC PIC 16C6X/7X Instructions, Addressing Modes, I/O Ports, Interrupts in PIC 16C61/71, PIC 16C61/71 Timers, PIC 16C71 Analog-to-Digital Converter (ADC)

**UNIT– 2**
**Introduction to DSP**
Introduction to the C2xx DSP core and code generation, The components of the C2xx DSP core, Mapping external devices to the C2xx core , peripherals and Peripheral Interface , System configuration registers , Memory , Types of Physical Memory , memory Addressing Modes , Assembly Programming using C2xx DSP, Instruction Set, Software Tools.

**UNIT– 3**
**I/O & Control Registers**
Pin Multiplexing (MUX) and General Purpose I/O Overview, Multiplexing and General Purpose I/O Control Registers .Introduction to Interrupts, Interrupt Hierarchy, Interrupt Control Registers, Initializing and Servicing Interrupts in Software.

**UNIT– 4**
**ADC & Event Manager**
ADC Overview , Operation of the ADC in the DSP , Overview of the Event manager (EV), Event Manager Interrupts , General Purpose (GP) Timers , Compare UNITs, Capture UNITs And Quadrature Enclosed Pulse (QEP) Circuitry , General Event Manager Information

**UNIT– 5**
**Introduction to Field Programmable Gate Arrays** – CPLD Vs FPGA – Types of FPGA , Xilinx C3000 series , Configurable logic Blocks (CLB), Input/Output Block (IOB) – Programmable Interconnect Point (PIP) – Xilinx 4000 series – HDL programming – overview of Spartan 3E and Virtex II pro FPGA boards- case study.

**Course Outcomes**: At the end of the course, student will be able to
- Design the interfacing circuits for input and output to PIC micro controllers and DSP processors.
- Write ALP for DSP processors.
- Design PWM controller for power electronic circuits using FPGA.

**Text Books:**
1. Microcontrollers-Theory and Applications - Ajay V Deshmukh, McGraw Hills, 2005.
2. DSP Based Electro Mechanical Motion Control -Hamid.A.Toliyat and Steven G.Campbell, CRC Press New York, 2004.

**Reference Books:**
1. The 8051 Microcontroller-Kennith J ayala, Thomson publishers,2005.
2. Microprocessor and Microcontrollers by Prof C.R.Sarma.
3. XC 3000 series datasheets ( version 3.1). Xilinx,Inc.,USA, 1998.
4. Wayne Wolf," FPGA based system design ", Prentice hall, 2004

| II-Semester | **Electric Drives Simulation Laboratory** | **Category** | **L-T-P 0-0-4** | **Credits 2** |
|---|---|---|---|---|

**Pre-requisite:** Power electronics & Drives

**Course Educational Objectives:**

The student should be able to understand the simulate different electrical machines and drives

**Any 10 of the following experiments are to be conducted.**

**List of Experiments:**

1. Simulation of DC shunt machine as motor & generator.
2. Simulate the speed control of DC motor using chopper converter.
3. Simulation of induction motor modes using d-q model.
4. Simulate the speed control of induction motor by using V/f control.
5. Simulate the BLDC motor and observe the speed transients.
6. Simulate speed control of induction motor by using vector control.
7. Compare the transient performance of induction motor controlled by v/f control & vector control methods.
8. Simulate PMSM motor by using d-q model.
9. Simulate the multi-level inverter fed induction motor drive.
10. Simulate the re-generative braking of inverter fed induction motor.
11. Study of PWM controlled inverter fed PMSM drive.
12. Evaluation of switching frequency effect on electric drive

**Course Objectives:**

The student should analyze the performance of different electrical machines and drives

| II-Semester | Electric Drives  Laboratory | Category | L-T-P 0-0-4 | Credits 2 |
|---|---|---|---|---|

**Course Educational Objectives:**
To study the speed control methods of DC & AC drives.

## Any 10 of the following experiments are to be conducted.

**List of experiments:**
1. Study of armature controlled separately excited DC drive with 1-$\phi$ full converter.
2. Study of chopper controlled separately excited DC drive.
3. Study of armature controlled separately excited DC drive with 3-$\phi$ full converter
4. Study of dynamic braking of DC drives.
5. Study of regenerative braking of DC drive.
6. Study of performance characteristics of a 3-$\phi$ induction motor using V/f control.
7. Vector control based speed control of induction motor.
8. Study of direct torque control of induction motor.
9. Speed control of PMSM drive with 3-$\phi$ inverter.
10. Speed control of BLDC drive with 3-$\phi$ inverter.
11. Speed control of switched reluctance motor drive.

**Course Outcome:**The student should Understand the performance of DC & AC drives.

| II-Semester | Mini Project with Seminar | Category | L-T-P 0-0-4 | Credits 2 |
|---|---|---|---|---|

**Note**:

It is recommended that a Supervisor/advisor should be allotted to each student at the end of the semester-I or allot at the start of the semester-II

**Syllabus content:**

A Student has to select one paper published in any of the IEEE Transactions and simulate the same. The student has to present the progress of the work at the middle of the semester. At the end of the semester, the student has to present the results by explaining the idea of the topic, methodology, finding of the simulations. A Student should also submit a report of the entire work carried out under this course. The end semester presentation must be video recorded and preserved.

| II-Semester | Audit Course-II | Category | L-T-P 2-0-0 | Credits 3 |
|---|---|---|---|---|
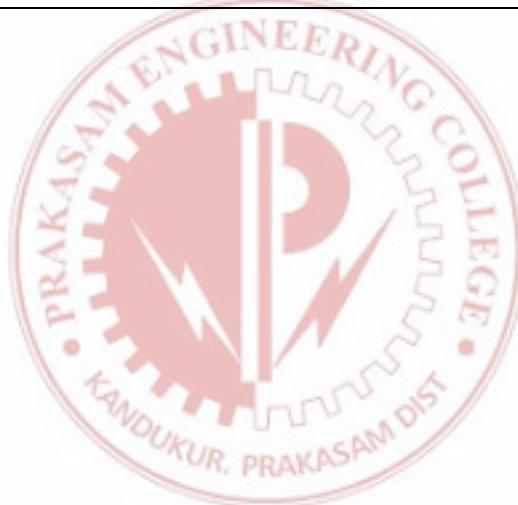
# PRAKASAM ENGINEERING COLLEGE
## KANDUKUR – 523105, Andhra Pradesh, India
### (R19 -M. Tech (Power Electronics) II YEAR COURSE STRUCTURE & SYLLABUS)

**III Semester**

| S. No | Course No | Category | Course Name | P.Os | L | T | P | C | Marks |
|-------|-----------|----------|-------------|------|---|---|---|---|-------|
| 1 | | PE | Program Elective – V<br>  i.    Digital Signal Processing Controlled Drives<br>  ii.   Smart Grid Technologies<br>  iii.  Modeling & Simulation of Power Electronic Systems | | 3 | 0 | 0 | 3 | 100 |
| 2 | | OE | Open Elective<br>  i.Industrial Safety<br>  ii.Energy Audit, Conservation & Management<br>  iii.Composite Materials | | 3 | 0 | 0 | 3 | 100 |
| 3 | | | Dissertation Phase - I<br>**(to be continued and evaluated next semester)** | | 0 | 0 | 20 | 10 | --- |
| | | | | | 6 | 0 | 20 | 16 | 200 |

**IV Semester**

| S. No | Course No | Category | Course Name | T | P | C | Marks |
|-------|-----------|----------|-------------|---|---|---|-------|
| 1 | | | Dissertation Phase-II<br>**(continued from III semester)** | 0 | 32 | 16 | 100 |
| | | | | 0 | 32 | 16 | 100 |

| III-Semester | Digital Signal Processor Controlled Drives (Program Elective - V) | Category | L-T-P 3-0-0 | Credits 3 |
|---|---|---|---|---|

**Pre-requisite:**
Applications of Digital Signal Processors, Power Electronic control of Electrical Drives.

**Course Educational Objectives:**
- To study DSP controllers.
- To learn coding in DSP"s to control the electric drive speed.
- To learn speed control methods for induction motor, PMSM, BLDC motors.

**UNIT-1**
**Overview of TMS320LF2407 DSP controller:** Review of Instruction Set, Interrupts, normalization and number formatting.
**UNIT-2**
**Clarke's and Park's transformations:** Review of Clarke's and Park's transformations, Implementation of Clarke's and Park's transformation using TMS320LF2407 DSP
**UNIT-3**
**Implementation of PWM Techniques for 3-Ph VSI:** Implementation of Sine-triangle and SVPWM withTMS320LF2407 DSP using the concept of imaginary switching time
**UNIT-4**
**Control of BLDC Motor:** Principle of operation with Drive control system, implementation of control system using TMS320LF2407 DSP
**UNIT-5**
**Control of PMSM:** Principle of operation with drive control system, implementation of vector control using TMS320 LF2407DSP
**UNIT-6**
**Control of Induction Motor:** Implementation of field-oriented control for the speed control of Induction Motor using TMS320LF2407 DSP.

**Course Outcomes**: At the end of the course, student will be able to
- Interface the DSP platform with sensors such as hall-effect voltage sensors,
- Use hall-effect current sensors, shaft encoder for data acquisition for motor drive applications
- Scale and normalize the data to suit the requirements of the drive system
- Exploit the architectural features of the DSP platform to design and implement
- Use algorithms for the realization of controllers, Pulse Width Modulators and observers

**Text Books:**
1. Hamid A. Toliyat: DSP Based Electromechanical Motion Control, 1st Edition, CRC Press, 2004

2. Ned Mohan, T.M. Undeland and William P. Robbins: Power Electronics: Converters, Applications, 3rd Edition, John Wiley & Sons, 2009

**Reference:**
1. Application Notes from the website of Texas Instruments.

| III-Semester | Smart Grid Technologies (Program Elective–V) | Category | L-T-P 3 -0-0 | Credits 3 |
|---|---|---|---|---|

**Pre-requisite**: Basic knowledge on smart concept communication protocols, renewable energy systems and electronic circuits.

**Course Educational Objectives:**
- To understand concept of smart grid and developments on smart grid.
- To understand smart grid technologies and application of smart grid concept in hybrid electric vehicles etc.
- To have knowledge on smart substations, feeder automation and application for

**UNIT – 1**
**Introduction to Smart Grid:** 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 on Smart Grid. Case study of Smart Grid.

**UNIT – 2**
**Smart Grid Technologies: Part 1:** Introduction to Smart Meters, Real Time Prizing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Phase Shifting Transformers.

**UNIT – 3**
**Smart Grid Technologies: Part 2:** Smart Substations, Substation Automation, Feeder Automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) & their application for monitoring & protection, Smart storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage, Wide Area Measurement System(WAMS), Phase Measurement Unit(PMU).

**UNIT – 4**
**Micro grids and Distributed Energy Resources:** Concept of micro grid, need & applications of microgrid, formation of microgrid, Issues of interconnection, protection & control of microgrid. Plastic & Organic solar cells, Thin film solar cells, Variable speed wind generators, fuel cells, microturbines, Captive power plants, Integration of renewable energy sources.

**UNIT – 5**
**Power Quality Management in Smart Grid:** Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.
**Information and Communication Technology for Smart Grid:** Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN).monitoring and protection.

**Course Outcomes:**

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

- Understand smart grids and analyze the smart grid policies and developments in smart grids.
- Develop concepts of smart grid technologies in hybrid electrical vehicles etc.
- Understand smart substations, feeder automation, GIS etc.
- Analyze micro grids and distributed generation systems.
- Analyze the effect of power quality in smart grid and to understand latest developments in ICT for smart grid.

**Text Books:**
1. Ali Keyhani, Mohammad N. Marwali, Min Dai "Integration of Green and Renewable Energy in Electric Power Systems", Wiley
2. Clark W. Gellings, "The Smart Grid: Enabling Energy Efficiency and Demand Response", CRC Press

**Reference Books:**

1. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, "Smart Grid: Technology and Applications", Wiley
2. Jean Claude Sabonnadière, NouredineHadjsaïd, "Smart Grids", Wiley Blackwell 19
3. Peter S. Fox Penner, "Smart Power: Climate Changes, the Smart Grid, and the Future of Electric Utilities", Island Press; 1 edition 8 Jun 2010
4. S. Chowdhury, S. P. Chowdhury, P. Crossley, "Microgrids and Active Distribution Networks." Institution of Engineering and Technology, 30 Jun 2009
5. Stuart Borlase, "Smart Grids (Power Engineering)", CRC Press
6. Andres Carvallo, John Cooper, "The Advanced Smart Grid: Edge Power Driving Sustainability: 1", Artech House Publishers July 2011

| III-Semester | Modeling and Simulation of Power Electronic Systems (Program Elective–V) | Category | L-T-P 3 -0-0 | Credits 3 |
|---|---|---|---|---|

**Pre-requisites:** Analysis of Power Electronic Converters

**Course Educational Objectives:**
- To learn the simulation techniques in Power Electronic Converters.
- To learn the modeling the Power Electronic Converters.
- To simulate control methods for Power Electronic Converters.

**UNIT-1**
**Introduction:** Challenges in computer simulation - Simulation process - mechanics of simulation, Solution techniques for time domain analysis - Equation solvers, circuit-oriented simulators.

**UNIT-2**
**Simulation of power electronic converters:** MNA and ST Approaches- Nodal Analysis, Modified Nodal Analysis, The Spare Tableau Approach, Nonlinear Circuits - The Newton-Raphson Method, Computation Time, Convergence Issues, Nonlinear Circuit Equations, Introduction to Transient Simulation - Introduction, Discretization of Time, Transient Analysis, Accuracy and Stability, Explicit and Implicit Schemes, Methods for Transient Simulation - FE, BE and TRZ, Transient Analysis in Circuit Simulation, Equivalent Circuit Approach: RC Circuit, Buck Converter; Some Practical Aspects: Undamped Oscillations, Ringing, Global Error in Switching Circuits, Round-off Error, Assessment of Accuracy, Singular Matrix Problem, Trapezoidal integration, M & N method for simulating power electronic converters (with buck converter as a representative example).

**UNIT-3**
**Switching function:** Introduction, Application of the switching function technique, Properties of the switching function, Voltage-Current relations in switched circuits - Single Switch, Parallel Switch, Pulse Width Modulation- Unipolar, PWM Signal of a composite function, bipolar square wave modulation, Mathematical Modeling of Buck Converter, Modeling using switching function-buck converter, Rectifier, 3-phase VSI inverter, matrix converter, m-phase rectifier. PWM rectifier topologies, Modeling of power electronic converters - PWM rectifier in different frames- abc, alpha-beta and d-q.

**UNIT-4**
**Modeling, simulation of switching converters with state space averaging, hybrid model:** State space approach, averaging method, State Space Averaging Technique – Modeling AND linearization of converter transfer functions- Hybrid Modeling for DC-DC converter.

**Course Outcomes:** After the completion of the course, student will be able to
- Understand the back ground activities i.e., numerical solution used in the simulation software.
- Can judge or properly choose the required numerical solver to be used for analysis.
- Can understand and debug the convergence problems occurring during simulation.

**Text book:**
1. M. B. Patil, V. Ramnarayanan, V. T. Ranganathan**:** *Simulation of Power Electronic Converters***,** 1st ed., Narosa Publishers, 2010

**Reference book:**
1. Ned Mohan, Undeland and Robbins**, "**Power Electronics: Converters, Design and control**"-** 2nd ed., John Wiley.

| II-Semester | Industrial Safety (Open Elective) | Category | L-T-P 3 -0-0 | Credits 3 |
|---|---|---|---|---|

**Pre-requisite:** Engineering Fundamentals

**Course Educational Objectives:**
- To learn safety aspects of any industrial area
- To learn fundamentals and types of maintenance engineering
- To learn causes and effects of wear and Corrosion and their prevention
- To learn identification of faults and their repair
- To learn preventive maintenance- periodic an preventive-maintenance of industrial systems

**Unit-I:** Industrial safety: Accident, causes, types, results and control, mechanical and electrical hazards, types, causes and preventive steps/procedure, describe salient points of factories act 1948 for health and safety, wash rooms, drinking water layouts, light, cleanliness, fire, guarding, pressure vessels, etc, Safety color codes. Fire prevention and firefighting, equipment and methods.

**Unit-II:** Fundamentals of maintenance engineering: Definition and aim of maintenance engineering, Primary and secondary functions and responsibility of maintenance department, Types of maintenance, Types and applications of tools used for maintenance, Maintenance cost & its relation with replacement economy, Service life of equipment.

**Unit-III:** Wear and Corrosion and their prevention: Wear- types, causes, effects, wear reductionmethods, lubricants-types and applications, Lubrication methods, general sketch, working andapplications, i. Screw down grease cup, ii. Pressure grease gun, iii. Splash lubrication, iv. Gravitylubrication, v. Wick feed lubrication vi. Side feed lubrication, vii. Ring lubrication, Definition, principle and factors affecting the corrosion. Types of corrosion, corrosion prevention methods.

**Unit-IV:** Fault tracing: Fault tracing-concept and importance, decision tree concept, need andapplications, sequence of fault-finding activities, show as decision tree, draw decision tree for problems in machine tools, hydraulic, pneumatic, automotive, thermal and electrical equipment‟s like, I. Any one machine tool, ii. Pump iii. Air compressor, iv. Internal combustion engine, v. Boiler, vi. Electrical motors, Types of faults in machine tools and their general causes.

**Unit-V:** Periodic and preventive maintenance: Periodic inspection-concept and need, degreasing, cleaning and repairing schemes, overhauling of mechanical components, overhauling of electrical motor, common troubles and remedies of electric motor, repair complexities and its use, definition, need, steps and advantages of preventive maintenance. Steps/procedure for periodic and preventive maintenance of:    i. Machine tools, ii. Pumps, iii. Air compressors, iv. Diesel generating (DG) sets, Program and schedule of preventive maintenance of mechanical and electrical equipment, advantages of preventive maintenance. Repair cycle concept and importance.

**Course Outcomes:** At the end of the course, the student should be able to
- Understand the general industrial requirements like lighting, cleanliness prevention from hazards and accidents.
- Analyze maintenance requirements of the industry and cost associated.
- Analyze wear and corrosion aspects of the industry and their prevention.
- Identify the faults prone areas and their repair and periodic maintenance.

**Reference Books:**
1. Maintenance Engineering Handbook, Higgins & Morrow, Da Information Services.
2. Maintenance Engineering, H. P. Garg, S. Chand and Company.
3. Pump-hydraulic Compressors, Audels, Mcgrew Hill Publication.
4. Foundation Engineering Handbook, Winterkorn, Hans, Chapman & Hall London.

| III-Semester | Energy Audit Conservation & Management (Open Elective) | Category | L-T-P 3 -0-0 | Credits 3 |
|---|---|---|---|---|

**Pre-requisite:** Concepts of utilization of electrical energy, electrical machines and electrical measurements.

**Course educational objectives:**
- To learn principle of energy audit as well as management for industries and utilities and buildings.
- To study the energy efficient motors and lighting.
- To learn power factor improvement methods and operation of different energy instruments.
- To compute depreciation methods of equipment for energy saving.

**UNIT– 1**
**Basic Principles of Energy Audit**
Energy audit- definitions, concept , types of audit, energy index, cost index ,pie charts, Sankey diagrams and load profiles, Energy conservation schemes- Energy audit of industries- energy saving potential, energy audit of process industry, thermal power station, building energy audit.

**UNIT– 2**
**Energy Management**
Principles of energy management, organizing energy management program, initiating, planning, controlling, promoting, monitoring, reporting. Energy manager, qualities and functions, language, Questionnaire – check list for top management

**UNIT– 3**
**Energy Efficient Motors and Lighting**
Energy efficient motors, factors affecting efficiency, loss distribution, constructional details, characteristics – variable speed , variable duty cycle systems, RMS - voltage variation-voltage unbalance-over motoring-motor energy audit. lighting system design and practice, lighting control, lighting energy audit

**UNIT– 4**
**Power Factor Improvement and energy instruments**
Power factor – methods of improvement, location of capacitors, Power factor with non-linear loads, effect of harmonics on p.f, p.f motor controllers – Energy Instruments- watt meter, data loggers, thermocouples, pyrometers, lux meters, tongue testers,application of PLC"s

**UNIT– 5**
**Economic Aspects and their computation**
Economics Analysis depreciation Methods, time value of money, rate of return, present worth method, replacement analysis, lifecycle costing analysis – Energy efficient motors. Calculation of simple payback method, net present value method- Power factor correction, lighting – Applications of life cycle costing analysis, return on investment.

**Course Outcomes**: At the end of the course, student will be able to
- Understand the principle of energy audit and their economic aspects.
- Recommend energy efficient motors and design good lighting system.
- Understand advantages to improve the power factor.
- Evaluate the depreciation of equipment.

**Text Books:**
1. Energy management by W.R.Murphy&G.Mckay Butter worth, Heinemann publications, 1982.
2. Energy management hand book by W.CTurner, John Wiley and sons, 1982.

**Reference Books:**
1. Energy efficient electric motors by John.C.Andreas, Marcel Dekker Inc Ltd-2nd edition,1995
2. Energy management by Paul o" Callaghan, Mc-graw Hill Book company-1st edition, 1998
3. Energy management and good lighting practice : fuel efficiency- booklet12-EEO.

| III-Semester | Composite Materials (Open Elective) | Category | L-T-P 3 -0-0 | Credits 3 |
|---|---|---|---|---|

**Pre-requisite**: Engineering Physics

**Course Educational Objectives:**

- To learn characteristics of composite materials and know effects of reinforcement
- To learn application of different fibers, understand rules of mixtures
- To learn manufacturing of ceramic matrix, carbon matrix and applications
- To learn preparation of moulding compounds ,properties and applications
- To learn strength and failure criteria

**UNIT–1**: INTRODUCTION: Definition – Classification and characteristics of Composite materials. Advantages and application of composites.Functional requirements of reinforcement and matrix. Effect of reinforcement (size, shape, distribution, volume fraction) on overall composite performance.

**UNIT – 2**: REINFORCEMENTS: Preparation-layup, curing, properties and applications of glass fibers, carbon fibers, Kevlar fibers and Boron fibers. Properties and applications of whiskers, particle reinforcements. Mechanical Behavior of composites: Rule of mixtures, Inverse rule of mixtures. Isostrain and Iso stress conditions.

**UNIT – 3:** Manufacturing of Metal Matrix Composites: Casting – Solid State diffusion technique, Cladding – Hot isostatic pressing, Properties and applications. Manufacturing of Ceramic Matrix Composites: Liquid Metal Infiltration – Liquid phase sintering. Manufacturing of Carbon – Carbon composites: Knitting, Braiding, Weaving. Properties and applications.

**UNIT–4:** Manufacturing of Polymer Matrix Composites: Preparation of Moulding compounds and prepregs – hand layup method – Autoclave method – Filament winding method – Compression moulding – Reaction injection moulding. Properties and applications.

**UNIT – 5:** Strength: Laminar Failure Criteria-strength ratio, maximum stress criteria, maximum strain criteria, interacting failure criteria, hydrothermal failure. Laminate first play failure-insight strength; Laminate strength-ply discount truncated maximum strain criterion; strength design using caplet plots; stress concentrations.

**Course Outcomes:** At the end of the course, students should be able to
- Understand characteristics and advantages of composite materials
- Acquire knowledge of reinforcement, glass fiber, etc.
- Identify the usage of metal matrix composites
- Understand manufacturing of polymer matrix composites
- Understand  manufacturing of polymer matrix composites
- Identify different types of failures.

**Text Books**:

1. Material Science and Technology – Vol 13 – Composites by R.W.Cahn – VCH, West Germany.

2. Materials Science and Engineering, An introduction. WD Callister, Jr., Adapted by R.Balasubramaniam, John Wiley & Sons, NY, Indian edition, 2007.

**Reference Books:**

1. Hand Book of Composite Materials-ed-Lubin.

2. Composite Materials – K.K.Chawla.

3. Composite Materials Science and Applications – Deborah D.L. Chung.

4. Composite Materials Design and Applications – Danial Gay, Suong V. Hoa, and Stephen W. Tasi.

| III SEMESTER | DISSERTATION PHASE-I | CATEGORY | L-T-P 0-0-20 | CREDIT 10 |
|---|---|---|---|---|
| IV SEMESTER | DISSERTATION PHASE-II | CATEGORY | L-T-P 0-0-32 | CREDIT 16 |