# ACADEMIC REGULATIONS
# COURSE STRUCTURE
# AND
# DETAILED SYLLABUS

## ELECTRICAL AND ELECTRONICS ENGINEERING

## for

## M.Tech. – POWER ELECTRONICS AND DRIVES

*(Applicable from 2018-2019 Batches)*

**UNIVERSITY COLLEGE OF ENGINEERING KAKINADA *(Autonomous)***

**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY: KAKINADA**

**KAKINADA - 533 003, ANDHRA PRADESH, INDIA**

## COURSE STRUCTURE

### I Semester

| S. No. | Subject | L | P | Credits |
|---|---|---|---|---|
| 1 | Electrical Machine Modeling and Analysis | 4 | -- | 3 |
| 2 | Analysis of Power Electronic Converters | 4 | -- | 3 |
| 3 | Power Electronic Control of Electrical Drives-I | 4 | -- | 3 |
| 4 | Power Quality | 4 | -- | 3 |
| 5 | Elective – I<br>i. Modern Control Theory<br>ii. Custom Power Devices<br>iii. Optimization Techniques | 4 | -- | 3 |
| 6 | Elective – II<br>i. Energy Auditing, Conservation and Management<br>ii Artificial Intelligence Techniques<br>iii. HVDC Transmission | 4 | -- | 3 |
| 7 | Simulation Laboratory | -- | 4 | 2 |
| | **Total Credits** | | | **20** |

### II Semester

| S.No. | Subject | L | P | Credits |
|---|---|---|---|---|
| 1 | Switched Mode Power Conversion | 4 | -- | 3 |
| 2 | Power Electronic Control of Electrical Drives-II | 4 | -- | 3 |
| 3 | Microcontrollers and its Applications to Power Electronic Systems | 4 | -- | 3 |
| 4 | Flexible AC Transmission Systems | 4 | -- | 3 |
| 5 | Elective – III<br>i. Renewable Energy Systems<br>ii. Hybrid and Electric Vehicles<br>iii. Industrial applications of Power Electronic Systems | 4 | -- | 3 |
| 6 | Elective – IV<br>i. Smart Grid Technologies<br>ii. Advanced Digital Signal Processing<br>iii. Programmable Logic Controllers & Applications | 4 | -- | 3 |
| 7 | Power Converters & Drives Laboratory | -- | 4 | 2 |
| | **Total Credits** | | | **20** |

**III Semester**

| S. No. | Subject | L | P | Credits |
|---|---|---|---|---|
| 1 | Comprehensive Viva-Voce | -- | -- | 2 |
| 2 | Seminar – I | -- | -- | 2 |
| 3 | Project Work - I | -- | -- | 16 |
| **Total Credits** | | | | **20** |

**IV Semester**

| S. No. | Subject | L | P | Credits |
|---|---|---|---|---|
| 1 | Seminar – II | -- | -- | 2 |
| 2 | Project Work - II | -- | -- | 18 |
| **Total Credits** | | | | **20** |

**I-I**

## Electrical Machine Modeling and Analysis

**L / P / Credits**
**4 / -- / 3**

**Prerequisites:** 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 behaviour of the electrical machines.
- To understand the dynamic behaviour 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.
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**Unit II: 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 III: Reference frame theory&Modeling of single phase Induction Machines**

Linear transformation-Phase transformation - three phase to two phase transformation (abc to $\alpha\beta 0$) and vice-versa, transformation to rotating reference frame, ($\alpha\beta 0$ to d q 0) and vice versa - Power equivalence- Mathematical modeling of single phase induction machines.

**Unit IV: 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 V: 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:**

After completion of this course the students will be able to:

- Apply knowledge of behaviour of DC motors to model and analyse for different applications.
- Analyse the characteristics of different types of DC motors to design suitable controllers
- Apply the knowledge of reference frame theory for AC machines to model the induction and Synchronous machines.

- Evaluate the steady state and transient behaviour of induction and synchronous machines to Propose the suitability of drives for different industrial applications
- Analyse the 2-Phase induction machines using voltage and torque equations to differentiate the behaviour and to propose their applications in real world.

**Reference Books:**

1. Electric Motor Drives - Modeling, Analysis& control -R.Krishnan- Pearson Publications-1st edition -2002
2. Analysis of Electrical Machinery and Drive systems – P.C.Krause, Oleg Wasynczuk, Scott D.Sudhoff – Second Edition-IEEE Press.
3. Dynamic simulation of Electric machinery using Matlab / Simulink –CheeMunOng-
4. Prentice Hall
5. P.S.Bhimbra,'' Generalised theory of Electrical Machines''-Fifth edition,Khanna publishers.

I-I

## Analysis of Power Electronic Converters

L / P / Credits
4 / -- / 3

**Prerequisites**: Power switching devices, characteristics & Commutation techniques.

**Course Educational Objectives:**

- To study the operation of AC voltage converters and controllers.
- To study the necessity requirement of power factor correction for converter circuits.
- To study the operation of inverters with and without PWM controller.
- To study the operation of different types of multilevel inverters.

**Unit I**

**AC voltage Controllers:** Single Phase AC Voltage Controllers with RLE loads- ac voltage controller with PWM control –synchronous tap changers Application numerical problems.
Three Phase AC Voltage controllers-Analysis of Controllers with star and delta connected resistive, resistive –inductive loads-Effects of source and load inductances–Application-numerical problems.

**Unit II**

**AC-DC converters:** Single phase fully controlled converters with– Evaluation of input power factor and harmonic factor-Continuous and Discontinuous load current-Power factor improvements-Extinction angle control-symmetrical angle control- PWM control numerical problems. Three Phase ac-dc Converters- fully controlled Converters with RL load– Evaluation of input power factor and harmonic factor-Continuous and Discontinuous load current-three phase dual converters-Power factor improvements-three phase PWM control -twelve pulse converters- numerical problems

**Unit III**

**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 IV**

**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 – numerical problems. Voltage Control of Three-Phase Inverters- Sinusoidal PWM- $60_0$ PWM- Third Harmonic 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- 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:** After completion of this course the students will be able to:

- Analyze the operation of phase controlled converters and AC voltage converters.
- Analyze the requirements of power factor correction in converter circuits.
- Describe and analyse the operation of 3-phase inverters with and without PWM techniques.
- Describe principles of operation and features of multilevel inverters.

**Reference books:**

1. Power Electronics-Md.H.Rashid –Pearson Education Third Edition- First IndianReprint-2008
2. Power Electronics- Ned Mohan, Tore M.Undelan and William P.Robbins –John Wiley& Sons -2nd Edition.
3. Power Electronics – Lander –Ed.2009
4. Modern power Electronics and AC Drives – B.K.Bose
5. Power Converter Circuits – William Shepherd & Li Zhang-Yes Dee Publishing PvtLtd.

I-I

**Power Electronic Control of Electrical Drives-I**

**L / P / Credits**
**4 / -- / 3**

**Prerequisites:** Knowledge of Power Electronics and Machines

**Course Educational Objectives:**
To familiarize students with the concept of electric drives, and to provide in-depth knowledge of power converters fed dc and ac drives in open and closed loop, and mathematical modeling of drives

**Course Outcomes:**

After completion of the course the student will be able to:

- Understand different parts of electric drives
- Understand different speed control and braking schemes for DC motors and induction motors
- Control the DC drives using power converters
- Understand power converters for induction motors

**Unit-I**
**Introduction:** Definition of electric drive, types of load; Speed-torque characteristic of driven unit/loads, motors, steady state and transient stability of drives; Classification and components of load torque; Selection of motor power capacity for different duty cycles.

**Unit-II**
**Speed Control of Motors:** Review of braking and speed control of dc motor and induction motor, multi-quadrant operation, loss minimization in adjustable speed drives.

**Unit-III**
**Converter fed DC Drives**: Principle of operation of converter fed separately excited dc motor drives, operation of dc drive under continuous and discontinuous armature current, armature voltage and current waveforms, effect of freewheeling diode, analysis and performance evaluation, expression for speed-torque characteristic; Dual converter fed dc drives.

**Unit-IV**
**Chopper fed DC Drives:** Principle of operation, control techniques, steady state analysis of time ratio control and current limit control, closed loop control of dc drives; current control techniques, mathematical model of chopper fed dc drive.

**Unit-V**
**Induction Motor Drives:** Constant V/f controlled induction motors, controlled current and controlled slip operations; variable frequency controlled induction motor drives; PWM inverter drives, operation of closed loop slip-speed controlled VSI and CSI fed ac drives, multi-quadrant operation.

**Reference Books :**


1. Dubey G. K., "Fundamentals of Electric Drives", 2nd Ed., Narosa Publishing House.2007.
2. Pillai S. K., "A First Course in Electric Drives", 2nd Ed., New Age International Private Limited.2008.
3. Mohan N., Undeland T.M. and Robbins W.P., "Power Electronics- Converters, Applications and Design", 3rd Ed., Wiley India.2008.
4. Dubey G. K., "Power Semiconductor Controlled Drives", Prentice- Hall International Editions. 2001.
5. Murphy J. M. D. and Turnbull F. G., "Power Electronics Control of AC Motors", Pregamon Press.1990.
6. Bose B. K., "Power Electronics and Variable Frequency Drives",IEEE Press, Standard Publisher Distributors. 2001.
7. Krishnan R., "Electric Motor Drives – Modeling, Analysis and Control", Prentice Hall of India Private Limited.

**I-I** **Power Quality** **L / P / Credits**
**4 / -- / 3**

**Prerequisites:** Knowledge on electric circuit analysis, power systems and power electronics.

**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 long duration voltage variation and flicker
- To know power quality aspects in distributed generation.

**Unit-1 Introduction**

Overview of Power Quality, Concern about the Power Quality, General Classes of Power Quality Problems, Transients, Long-Duration Voltage Variations, Short, Duration Voltage Variations, Voltage Unbalance, Waveform Distortion, Voltage fluctuation, Power Frequency Variations, Power Quality Terms, Voltage Sags and Interruptions - Sources of Sags and Interruptions, Nonlinear loads.

**Unit-2 Transient Over Voltages**

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, Computer Tools for Transient Analysis

**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 Long Duration Voltage Variations**

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 Resources, Flicker

**Unit-5 Distributed Generation and Power Quality**

Resurgence of Distributed Generation, DG Technologies, Interface to the Utility System, Power Quality Issues, Operating Conflicts, DG on Low Voltage Distribution Networks, Interconnection standards, Wiring and Grounding, Typical Wiring and Grounding Problems, Solution to Wiring and grounding Problems

**Course Outcomes:**

After completion of this course the students will be able to:

- Have the knowledge on causes of power quality, power quality parameters.

- Understand sources of transient over voltages and providing protection to transient over voltages.
- Understand effects of harmonics, sources of harmonics and harmonic minimization.
- Analyze long duration voltage variations and regulation of voltage variations.
- Describe power quality aspects in distributed generation and develop solutions to wiring and grounding problems.

**Reference Books :**

1. Electrical Power Systems Quality, Dugan R C, McGranaghan M F, Santoso S, and Beaty H W, Second Edition, McGraw-Hill, 2002.
2. Power Quality Primer, Kennedy B W, First Edition, McGraw-Hill, 2000.
3. Understanding Power Quality Problems: Voltage Sags and Interruptions, Bollen M H J, First Edition, IEEE Press; 2000.
4. Power System Harmonics, Arrillaga J and Watson N R, Second Edition, John Wiley & Sons, 2003.
5. Electric Power Quality control Techniques, W. E. Kazibwe and M. H. Sendaula, Van Nostrad Reinhold, New York.
6. Power Quality c.shankaran, CRC Press, 2001
7. Harmonics and Power Systems –Franciso C.DE LA Rosa-CRC Press (Taylor & Francis)
8. Power Quality in Power systems and Electrical Machines-EwaldF.fuchs, MohammadA.S. Masoum-Elsevier

**I-I**

## Modern Control Theory (Elective-I)

**L / P / Credits**
**4 / -- / 3**

**Prerequisites:** 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, State diagram - Linear Continuous time model for physical systems – Existence and Uniqueness of Solutions to Continuous, Time State Equations – Solutions – Linear Time Invariant Continuous, Time State Equations, State transition matrix and it's properties

**Unit – 2: State Variable Techniques**

General concept of Controllability - General concept of Observability Controllability tests for Continuous &Time Invariant systems, Observability tests for Continuous &Time Invariant systems - Controllability and Observability of state model in Jordan Canonical form - Controllability and Observability Canonical forms of State model – State feedback controller design through pole assignment.

**Unit – 3: Non Linear Systems – I**

Introduction – Non Linear Systems – Types of Nonlinearities – Saturation – Dead Zone – Backlash – Jump Phenomenon etc; - Singular Points – Introduction to Linearization of nonlinear systems, properties of Non Linear Systems – Describing function – describing function analysis of nonlinear systems- Stability analysis of Nonlinear systems through describing functions.

**Unit – 4: Non Linear Systems – II**

Introduction to phase plane analysis, Method of Isoclines for Constructing Trajectories, singular points, phase plane analysis of nonlinear control systems.

**Unit – 5: Stability Analysis**

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

**Course Outcomes:**

After completion of this course the students will be able to:

- Understanding the state variable approach is suitable for higher order.
- To analyze the concepts of controllability and observability.
- To analyze the various non-linearities through describing functions and phase plane analysis.
- Typical issues of stability and instability of continuous time invariant systems.

**Reference Books :**

1. Modern Control System Theory by M. Gopal – New Age International – 1984
2. Modern Control Engineering by Ogata. K – Prentice Hall – 1997
3. Nonlinear systems, Hassan K. Klalil, Prentice Hall, 1996
4. Modern control systems, Richard C. Dorf and Robert H. Bishop, 11th Edition, Pearson Edu, India, 2009

**I-I** **Custom Power Devices (Elective-I)** **L / P / Credits**
**4 / -- / 3**

**Prerequisites:** Concept of power electronics and concept of reactive power compensation.

**Course Educational Objectives:**

- To understand the various power quality issues and their effects on the distribution circuits.
- To understand principle of working of various custom power devices.
- To understand the other custom power devices and their applications to power system.

**Unit I- Introduction**
Custom Power and Custom Power Devices, power quality variations in distribution circuits: Voltage Sags, Swells, and Interruptions. System Faults, over voltages and under voltages, Voltage Flicker, Harmonic Distortion, Voltage Notching, Transient Disturbances, Characteristics of Voltage Sags.

**Unit II- Overview of Custom Power Devices**
Reactive Power and Harmonic Compensation Devices, Compensation Devices for Voltage Sags and Momentary Interruptions, Backup Energy Supply Devices, Battery UPS, Super Conducting Magnetic Energy Storage systems, Flywheel.

**Unit III- Reactive Power and Harmonic Compensation Devices**
Var control devices - Static Var Compensator, Topologies, Direct Connected Static Var Compensation for Distribution Systems, Static Series Compensator, Static Shunt Compensator (DSTATCOM): Interaction with Distribution Equipment and System, Installation Considerations.

**Unit IV- High-Speed Source Transfer Switches, Solid State Limiting, and Breaking Devices:**
Source Transfer Switch , Static Source Transfer Switch (SSTS),- Hybrid source transfer switch – High-speed mechanical source transfer switch - Solid state current limiter - Solid state breaker .

**Unit V- Application of Custom Power Devices in Power Systems**
P-Q theory – Control of P and Q, Dynamic Voltage Restorer (DVR): Operation and control – Interline Power Flow Controller (IPFC): Operation and control – Unified Power Quality Conditioner (UPQC): Operation and control.

**Course Outcomes:**
After completion of this course the students will be able to:

- Analyse the effect of various power quality issues in distribution system and their mitigation principles.
- Describe the operation of custom power devices for reactive power & harmonic compensation.
- Analyse high speed transfer switches.
- Analyse the operation and control of custom power devices in power system applications.

**Text Books**

1. Guidebook on Custom Power Devices, Technical Report, Published by EPRI, Nov 2000
2. Power Quality Enhancement Using Custom Power Devices – Power Electronics and Power Systems, Gerard Ledwich, Arindam Ghosh, Kluwer Academic Publishers, 2002.

**Reference Books:**

1. Power Quality, C. Shankaran, CRC Press, 2001
2. Instantaneous power theory and application to power conditioning, H. Akagiet.al., IEEE Press, 2007.
3. Custom Power Devices - An Introduction, ArindamGhosh and Gerard Ledwich, Springer, 2002
4. 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-I

## Optimization Techniques (Elective-I)

**L / P / Credits**
**4 / -- / 3**

**Prerequisites:** Concepts of engineering mathematics and mathematical methods.

**Course Educational Objectives:**

- To define an objective function and constraint functions in terms of design variables, and then state the optimization problem.
- To state single variable and multi variable optimization problems, without and with constraints.
- To explain linear programming technique to an optimization problem, define slack and surplus variables, by using Simplex method.
- To study and explain nonlinear programming techniques, unconstrained or constrained, and define exterior and interior penalty functions for optimization problems.
- To introduce evolutionary programming techniques.
- To introduce basic principles of Genetic Algorithms and Partial Swarm Optimization methods.

**Unit I**
**Introduction and Classical Optimization Techniques:**
Statement of an Optimization problem – design vector – design constraints – constraint surface – objective function – objective function surfaces – classification of Optimization problems. Single variable Optimization – multi variable Optimization without constraints – necessary and sufficient conditions for minimum/maximum – multivariable Optimization with equality constraints.Solution by method of Lagrange multipliers – multivariable Optimization with inequality constraints – Kuhn – Tucker conditions.

**Unit II**
**Linear Programming**
Standard form of a linear programming problem – geometry of linear programming problems – definitions and theorems – solution of a system of linear simultaneous equations – pivotal reduction of a general system of equations – motivation to the simplex method – simplex algorithm - Duality in Linear Programming – Dual Simplex method.

**Unit III**
**Nonlinear Programming:**
**Unconstrained cases -** One – dimensional minimization methods: Classification, Fibonacci method and Quadratic interpolation method - Univariate method, Powell's method and steepest descent method.
**Constrained cases -** Characteristics of a constrained problem, Classification, Basic approach of Penalty Function method; Basic approaches of Interior and Exterior penalty function methods.Introduction to convex Programming Problem.

**Unit IV**
**Introduction to Evolutionary Methods:**
Evolutionary programming methods - Introduction to Genetic Algorithms (GA)– Control parameters –Number of generation, population size, selection, reproduction, crossover and mutation – Operator selection criteria – Simple mapping of objective function to fitness function – constraints – Genetic algorithm steps – Stopping criteria –Simple examples.

**Unit V**
**Introduction to Swarm Intelligence Systems:**
Swarm intelligence programming methods - Basic Partial Swarm Optimization – Method – Characteristic features of PSO procedure of the global version – Parameters of PSO (Simple PSO algorithm – Operators selection criteria – Fitness function constraints) – Comparison with other evolutionary techniques – Engineering applications of PSO.

**Course Outcomes:**
After completion of this course the students will be able to:
- State and formulate the optimization problem, without and with constraints, by using design variables from an engineering design problem.
- Apply classical optimization techniques to minimize or maximize a multi-variable objective function, without or with constraints, and arrive at an optimal solution.
- Formulate a mathematical model and apply linear programming technique by using Simplex method. Also extend the concept of dual Simplex method for optimal solutions.
- Apply gradient and non-gradient methods to nonlinear optimization problems and use interior or exterior penalty functions for the constraints to derive the optimal solutions.
- Able to apply Genetic algorithms for simple electrical problems.
- Able to solve practical problems using PSO.

**Text Books**
1. "Engineering optimization: Theory and practice"-by S. S.Rao, New Age International (P) Limited, 3rd edition, 1998.
2. Soft Computing with Matlab Programming by N.P.Padhy&S.P.Simson, Oxford University Press – 2015

**Reference Books:**
1. **"**Optimization methods in operations Research and Systems Analysis" by K.V.Mital and C.Mohan, New Age International (P) Limited, Publishers, 3rd edition, 1996.
2. Genetic Algorithms in search, optimization, and Machine Learning by David E.Goldberg,ISBN:978-81-7758-829-3, Pearsonby Dorling Kindersley (India) Pvt. Ltd.
3. "Operations Research: An Introduction" by H.A.Taha, PHI pvt. Ltd., 6th edition.
4. Linear Programming by G.Hadley.,Narosa Publishers.

**I-I** **Energy Auditing, Conservation and Management (Elective-II)** **L / P / Credits 4 / -- / 3**

**Prerequisites:**
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 I: 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 II: Energy Management**
Principles of energy management, organizing energy management program, initiating, planning, controlling, promoting, monitoring, reporting. Energy manger, qualities and functions, language, Questionnaire – check list for top management

**UNIT III: Energy Efficient Motors and Lighting**
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. Good lighting system design and practice, lighting control, lighting energy audit

**UNIT IV: 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 V: 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:** After completion of this course the students will be able to:

- Perform energy audit in different organizations.
- Recommend energy efficient motors and design good lighting system.
- Understand advantages to improve the power factor.
- Evaluate the depreciation of equipment.

**Reference Books:**

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

I-I

## Artificial Intelligence Techniques (Elective-II)

L / P / Credits
4 / -- / 3

**Prerequisites:** Basic knowledge on human biological systems, concept of optimization and electrical engineering.

**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 power electronics and DC drives.

**Unit I: Introduction to Neural Networks**

Introduction, Humans and Computers, Biological Neural Networks, Historical development of neural network, Terminology and Topology, Biological and artificial neuron models, Basic learning laws.

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**Unit II: Feed Forward Neural Networks**

Introduction, Perceptron models: Discrete, continuous and multi-category, Training algorithms: Discrete and Continuous Perceptron Networks, Perceptron convergence theorem, Limitations and applications of the Perceptron model, Generalized delta learning rule, Feedforward recall and error back propagation training-Radial basis function algorithms-Hope field networks

**Unit III: Genetic algorithms &Modelling-**introduction-encoding-fitness function-reproduction operators-genetic operators-cross over and mutation-generational cycle-convergence of genetic algorithm

**Unit IV: Classical and Fuzzy Sets**

Introduction to classical sets - properties, operations and relations; Fuzzy sets, membership, Uncertainty, operations, properties, fuzzy relations, cardinalities, membership functions. Fuzzy Logic System Components-Fuzzification, Membership value assignment, development of rule base and decision making system, defuzzification to crisp sets, defuzzification methods.

**Unit V: Application of AI Techniques:** PWM Controllers -Selected harmonic elimination PWM Space vector PWM using neural network. Design of PI controller for speed control of DC motor using fuzzy logic-

**Course Outcomes:** After completion of this course, students will be able to

- Understand neural networks and analyze different types of neural networks.
- Design training algorithms for neural networks.
- Develop algorithms using genetic algorithm for optimization.
- Analyze and design fuzzy logic systems.
- Apply AI Techniques in power electronics and DC drives.

**Reference Books:**

1. Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications by Rajasekharan andPai – PHI Publication.
2. Introduction to Artificial Neural Systems - Jacek M. Zuarda, Jaico Publishing House, 1997.
3. Modern Power Electronics and AC Drives –B.K.Bose-Pearson Publications
4. Genetic Algorithms- David E Goldberg. Pearson publications.

**I-I**

## HVDC Transmission (Elective-II)

**L / P / Credits**
**4 / -- / 3**

**Prerequisites:** Knowledge on Power Electronics, Power Systems and High Voltage Engineering

**Course Educational Objectives:**

- To learn various schemes of HVDC transmission.
- To learn about the basic HVDC transmission equipment.
- To learn the control of HVDC systems.
- To be exposed to the interaction between HVAC and HVDC system.
- To be exposed to the various protection schemes of HVDC engineering.

**Course Outcomes:**

After completion of the course the student will be able to:

- Understand the various schemes of HVDC transmission.
- Understand the basic HVDC transmission equipment.
- Understand the control of HVDC systems.
- Understand the interaction between HVAC and HVDC system.
- Understand the various protection schemes of HVDC engineering.

**Unit-I: Introduction:**

Introduction to HVDC transmission, Comparison between HVAC and HVDC systems, economic technical and reliability aspects, limitations, types of HVDC links, mono-polar, bipolar and homo-polar links, Components of HVDC transmission system.

**Unit-II: Static power converters:**

Basic conversion principles, 6-pulse bridge circuit and analysis with and without overlapping , rectifier and inverter operation, equivalent circuit of converter and HVDC links, special features of converter transformers, waveforms, factors responsible for generation of harmonics, voltage and current harmonics, effect on variation of $\alpha$ and $\mu$, Filters and harmonic elimination.

**Unit-III: Control of HVDC converters and systems:**

Design features of HVDC system control, constant current, constant extinction angle and constant ignition angle control, individual phase control and equidistant firing angle control, DC power flow control, starting and stopping HVDC link, reversal of power in HVDC link.

**Unit-IV:**

**Interaction between HVAC and DC systems:**

Voltage interaction, dynamic stabilization of AC systems, harmonic instability problems and DC power modulation.

Multi terminal DC links and systems:

Series, parallel and series-parallel systems, their operation and control.

**Unit-V:**

**Transient over voltages in HVDC systems:**

Over voltages due to disturbances on DC side, over voltages due to DC and AC side line faults.

Converter faults and protection in HVDC systems:

Converter faults, over current protection, valve group and DC line protection, DC circuit breakers, over voltage protection of converters, surge arresters.

**Reference Books :**

1. S Kamakshaih and V Kamaraju:HVDC Transmission- MG hill.
2. K.R.Padiyar : High Voltage Direct current Transmission, Wiley Eastern Ltd., New Delhi– 1992.
3. E.W. Kimbark : Direct current Transmission, Wiley Inter Science – New York.
4. J.Arillaga : H.V.D.C.Transmission Peter Peregrinus ltd., London UK 1983
5. Vijay K Sood :HVDC and FACTS controllers:Applications of static converters in power systems by, Kluwer Academic Press.

**I-I** **Simulation Laboratory** **L / P / Credits**
**-- / 4 /** 2

**Prerequisites:** Concepts of Power Electronics & Closed loop control.

**Course Educational Objectives:**

- To understand the characteristics of Thyristor, MOSFET & IGBT by simulation.
- To understand the operation of power electronics converters by simulation.
- To understand how to implement PWM techniques in simulation.
- To understand and analyse the speed control of AC motors in open and closed loop in simulation.

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

**List of experiments:**

1. Switching characteristics simulation and analysis of Thyristor, MOSFET, IGBT .
2. Simulation and analysis of single phase full converter using R-L load, R-L-E load with and without LC Filter.
3. Simulation and analysis of three phase full converter using R-L-E Load.
4. Simulation and analysis of single phase ac Voltage controller with PWM control for RL load.
5. Simulation and analysis of three phase ac Voltage controller using RL load.
6. Simulation and analysis of single phase inverter with sinusoidal PWM control for R& RL loads.
7. Simulation and analysis of three phase inverter with Sinusoidal PWM control for R& RL loads.
8. Simulation and analysis of Buck, Boost and Buck-Boost DC-DC converters.
9. Simulation and analysis of three phase converter fed dc motor.
10. Development of mathematical model, simulation and analysis of induction machines under balanced and symmetrical conditions for the following cases.
    a. dq model in synchronous reference frame
    b. dq model in stator reference frame
    c. dq model in rotor reference frame
11. Simulation and analysis of Volts/Hz closed-loop speed control of an induction motor drive.
12. Simulation and analysis of Open-loop Volts/Hz control of a synchronous motor drive.
13. Simulation and analysis of speed control of a permanent magnet synchronous motor.
14. Simulation and analysis of capacitor-start capacitor-run single-phase induction motor.

**COURSE OUTCOMES:** After completion of this course the students will be able to:

- Analyse the characteristics of power semiconductor devices in simulation.
- Analyse the operation of various power electronic converters in simulation.
- Analyse and implementing the speed controlling techniques for AC machines in simulation.
- Analyse and implementing PWM techniques in simulation.

I-II

## Switched Mode Power Conversion

L / P / Credits
4 / -- / 3

**Perquisites:** 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 analyse the switch mode converters using small-signal analysis.

**Unit-I: Non-isolated switch mode converters:**
Control of DC-DC converters: Buck converters, Boost converters, Buck-Boost converter, CUK Converter, Converter realization with non-ideal components.

**Unit-II: 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-III: Isolated switched mode converters:**
Forwarded converter, flyback converter, push-pull converter, half-bridge converter, full bridge converter

**Unit-IV: Control schemes of switching converters:**
Voltage control, Current control, control scheme for resonant converters, proportional integral controller.
Magnetic design consideration: Transformers design, dc inductor and capacitor design.

**Unit-V: Modeling and Control design based on linearization:**
Formulation of averaged models for buck and boost converters average circuits models, small –signal analysis and linearization.
Control design based on linearization: Transfer function of converters, control design, large signal issues in voltage-mode and current-mode control.

**Course Outcomes:**

After completion of this course the students will be able to:

- Analyse the control operation of non-isolated switch mode converters.
- Analyse the operation of resonant converters and soft switching.
- Analyse the operation of isolated switch mode converters.
- Analyse the control schemes for resonant converters and design of magnetic components.
- Analyse the design of non-isolated switch mode converters based on linearization.
- Analyse the switch mode converters with small signal analysis.

**Reference Books:**

1. Power Electronics – Issa Batareseh, Jhon Wiley publications,2004
2. Power switching converters-simon Ang, Alejandro olive, CRC Press (Taylor&franics group).
3. Elements of Power Electronics – Philip T. Krein, Oxford University press.
4. Power Electronics: converters Applications & Design – Mohan, Undeland, Robbins-
5. Wiley publications

**I-II** **Power Electronic Control of Electrical Drives-II** **L / P / Credits**
**4 / -- / 3**

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

**Course Outcomes:**

After completion of the course the student will be able to:

- Advantages and applications of induction motor drives
- Understand sensor less control of induction motor drives
- Understand DTC of IM drives
- Understand the advantages and control of PMSM, BLDC and SRM drives.

**Unit-I: Vector Control of Induction Motor Drive:**
Principle of vector control, methods of vector control, direct vector control, indirect vector control, rotor flux oriented control, stator flux oriented control, air gap flux oriented control, decoupling circuits.

**Unit-II: 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-III: 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-IV: 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 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-V: 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

**Reference 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.

**I-II Microcontrollers and its Applications to Power Electronic Systems L / P / Credits**
**4 / -- / 3**

**Prerequisites:** Basic concepts of switching theory & logic design and fundamentals of micro controllers.

**Course Educational Objectives:**

- To understand the architecture of PIC micro controller.
- To understand the architecture of DSP processor and their interface.
- To understand how to write the program for DSP processor using assembly Programming.
- To understand the different types of FPGA and configurations.
- To understand the basics of programming in Xilinx.

**Unit I**
**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 II**
**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 III**
**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 IV**
**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 V**

Introduction to Field Programmable Gate Arrays – CPLD Vs FPGA – Types of FPGA , Xilinx XC3000 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:**

After completion of this course the students will be able to:

- Know the interfacing circuits for input and output to PIC micro controllers and DSP processors.
- Know how to write ALP for DSP processors.
- Design PWM controls for power electronic circuits using FPGA.

**Reference Books:**

1. Microcontrollers-Theory and Applications by Ajay V Deshmukh, McGraw Hills
2. Microcontrollers by Kennith J ayala, Thomson publishers
3. Microprocessor and Microcontrollers by Prof C.R.Sarma.
4. Hamid.A.Toliyat and Steven G.Campbell"DSP Based Electro Mechanical Motion Control " CRC Press New York , 2004.
5. XC 3000 series datasheets ( version 3.1). Xilinx,Inc.,USA, 1998.
6. Wayne Wolf," FPGA based system design ", Prentice hall, 2004

**I-II**

## Flexible AC Transmission Systems

**L / P / Credits**
**4 / -- / 3**

**Prerequisites:** Concepts on Power Electronics and Power Systems

**Course Educational Objectives:**

- To study the performance improvements of transmission system with FACTS.
- To study the effect of static shunt compensation.
- To study the effect of static series compensation.
- To study the effect of UPFC.

**Unit 1**

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 2**

Basic concept of voltage and current source converters, comparison of current source converters with voltage source converters. Static shunt compensation : Objectives of shunt compensation, midpoint voltage regulation, voltage instability prevention, improvement of transient stability, Power oscillation damping, methods of controllable var generation: variable impedance type static var generators, switching converter type var generators, hybrid var generators.

**Unit 3**

SVC and STATCOM operating principles : The regulation slope ,V-I characteristics, transient stability enhancement and power oscillation damping, operating point control and summary of compensation control.

**Unit 4**

Static series compensators : Concept of series capacitive compensation, improvement of transient stability, power oscillation damping, functional requirements. GTO thyristor controlled series capacitor (GSC), thyristor switched series capacitor (TSSC), and thyristor controlled series capacitor (TCSC), Static Synchronous Series Compensator (SSSC), control schemes for GSC, TSSC,TCSC and SSSC.

**Unit 5**

UPFC and IPFC: Basic operating principle, conventional transmission control capabilities, independent real and reactive power flow control. IPFC operating principle, control schemes for IPFC.

**Course Outcomes:**

After completion of the course, the student will be able to:

- Know the performance improvement of transmission system with FACTS.
- Get the knowledge of effect of static shunt and series compensation.
- Know the effect of UPFC.
- Determine an appropriate FACTS device for different types of applications.

**Reference Books :**

1. “Understanding FACTS Devices” N.G.Hingorani and L.Guygi, IEEE Press. Indian Edition is available:--Standard Publications
2. Sang.Y.Hand John.A.T, “Flexible AC Transmission systems” IEEE Press (2006).
3. HVDC & FACTS Controllers: applications of static converters in power systems- Vijay K.Sood- Springer publishers

**I-II**

## Renewable Energy Systems (Elective-III)

**L / P / Credits**
**4 / -- / 3**

**Prerequisites:** Basic idea of non-conventional energy sources.

**Course Educational Objectives:**

- To learn basic principle of renewable energy sources.
- To adoption of alternative energy sources for power generation.
- To learn alternative energy sources not based on sun.
- To the adoption and inter connection of renewable and alternative energy sources to grid.

**Course Outcomes:**

After completion of the course the student will be able to:

- Identify alternate energy sources.
- Classify and analyze Power and Losses in Induction generators.
- Adopt different alternate energy sources for power generation.

**Unit I**

**Introduction:** Renewable Sources of Energy; Grid-Supplied Electricity; Distributed Generation; Renewable Energy Economics - Calculation of Electricity Generation Costs; Demand-Side Management Options; Supply-Side Management Options; Modern Electronic Controls of Power Systems

**Unit-II**

**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; Economical Aspects.

**Unit III**

**Wind Power Plants:** Appropriate Location; Evaluation of Wind Intensity; Topography; Purpose of the Energy Generated - 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 Generating System

**Unit IV**

**Photovoltaic Power Plants:** Solar Energy; Generation of Electricity by Photovoltaic Effect; Dependence of a PV Cell Characteristic on Temperature; Solar Cell Output Characteristics - Equivalent Models and Parameters for Photovoltaic Panels; MPPT schemes: P&O,INC, Fuzzy logic, effect of partial shaded condition. Photovoltaic Systems - Applications of Photovoltaic Solar Energy; Economical Analysis of Solar Energy

**Unit V**

**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 and Related Precautions; Advantages and Disadvantages of Fuel Cells - Fuel Cell Equivalent Circuit; Practical Determination of the Equivalent Model Parameters; Aspects of Hydrogen as Fuel

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

**I-II** **Hybrid and Electric Vehicles (Elective-III)** **L / P / Credits**
**4 / -- / 3**

**Prerequisites:** Knowledge of Power Electronics and Electric Drives

**Course Educational Objectives:**
To familiarize students with the concept of hybrid vehicles, types of electric drives used in hybrid vehicles and their control.

**Course Outcomes:**

After completion of the course the 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.

**Unit-I**
Introduction: History of hybrid vehicles, architectures of HEVs, series and parallel HEVs, complex HEVs.

**Unit-II**
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-III**
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-IV**
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-V**
**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

**Reference Books :**

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

**I-II** **L / P / Credits**

**Industrial applications of Power Electronic Systems (Elective-III)** **4 / -- / 3**

**Course Educational Objectives:**

To provide broad knowledge on industrial application of power electronics and selection of power electronic components for partial applications.

**Course Outcomes:** After completion of the course the student will be able to:

- Design power converters for LED lightning systems
- Analyze uninterrupted power supplies
- Select different electrical drives for electric traction systems
- Differentiate linear machines and rotating machines

**Unit-I: LED Lightning Systems:**

LED lightning systems, types of industrial LED lightning systems, LED characteristics, converters for LED lightning systems, Illumination control of LEDs for different applications.

**Unit-II: UPS and SMPS**

Components of UPS, operation and applications of UPS, basic operation and applications of SMPS, difference between UPS and SMPS.

Servo stabilizers: Principle and operation of Servo stabilizers, applications of Servo stabilizers.

**Unit-III: Electrical Traction Systems:**

Selection of motor for traction applications, advantages of electric traction, characteristics of traction motors, electric braking of traction motors, power supply management in traction system.

**Unit-IV: Stepper motors and control:**

Construction of Stepper motor, types of Stepper motor, operation of Stepper motor, characteristics of Stepper motor, applications of Stepper motor, open loop and closed loop control of stepper motors.

**Unit-V: Linear machines and control:**

Linear Induction Motor: Principle of operation of Linear Induction Motor, types of Linear Induction Motor, Characteristics and applications of Linear Induction Motor, control of linear induction motor for magnetic levitation.

Linear Synchronous Motor: Principle of operation of Linear Synchronous Motor, types of Linear Synchronous Motor, Characteristics and applications of Linear Synchronous Motor.

**Reference Books :**

1. Michael Jacob, "Industrial Control Electronics – Applications and Design", Prentice Hall, 1988.
2. Thomas, E. Kissel, "Industrial Electronics" PHI, 2003.
3. James Maas, "Industrial Electronics", Prentice Hall, 1995.

**I-II** **Smart Grid Technologies (Elective-IV)** **L / P / Credits 4 / -- / 3**

**Prerequisites:** 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 monitoring and protection.
- To have knowledge on micro grids and distributed energy systems.
- To know power quality aspects in smart grid.

**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 Pricing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation and Phase Shifting Transformers.

**Unit 3**

**Smart Grid Technologies: Part 2:** Smart Substations, Substation Automation, Feeder Automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) and 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**

**Microgrids and Distributed Energy Resources:** Concept of micro grid, need and applications of microgrid, formation of microgrid, Issues of interconnection, protection and control of microgrid. Variable speed wind generators, fuelcells, microturbines, Captive power plants, Integration of renewable energy sources.

**Unit 5**

**Power Quality Management in Smart Grid:** Power Quality and 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), WideArea Network (WAN).

**Course Outcomes:**

After completion of this course the students will be able to:

- Understand smart grids and analyse 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.
- Analyse micro grids and distributed generation systems.
- Analyse 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
3. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama,"Smart Grid: Technology and Applications", Wiley
4. Jean Claude Sabonnadière, NouredineHadjsaïd, "Smart Grids", Wiley Blackwell 19
5. Peter S. Fox Penner, "Smart Power: Climate Changes, the Smart Grid, and the Future of Electric Utilities", Island Press; 1 edition 8 Jun 2010
6. S. Chowdhury, S. P. Chowdhury, P. Crossley, "Microgrids and Active Distribution Networks." Institution of Engineering and Technology, 30 Jun 2009
7. Stuart Borlase, "Smart Grids (Power Engineering)", CRC Press

**Reference Books:**

1. Andres Carvallo, John Cooper, "The Advanced Smart Grid: Edge Power Driving Sustainability: 1", Artech House Publishers July 2011
2. James Northcote, Green, Robert G. Wilson "Control and Automation of Electric Power Distribution Systems (Power Engineering)", CRC Press
3. MladenKezunovic, Mark G. Adamiak, Alexander P. Apostolov, Jeffrey George Gilbert "Substation Automation (Power Electronics and Power Systems)", Springer
4. R. C. Dugan, Mark F. McGranghan, Surya Santoso, H. Wayne Beaty, "Electrical Power System Quality", 2nd Edition, McGraw Hill Publication
5. Yang Xiao, "Communication and Networking in Smart Grids", CRC Press

**I-II** **Advanced Digital Signal Processing (Elective-IV)** **L / P / Credits**
**4 / -- / 3**

**Prerequisites:** Knowledge on signal processing and Z-transform.

**Course Educational Objectives:**

- To have knowledge on structures of different digital filters.
- To design digital filters with different techniques.
- To understand the implementation aspects of digital filters.
- To analyze the effect of finite word length in signal processing.
- To understand power spectrum estimation techniques in signal processing.

**Unit I**

**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 II**

**Digital filter design:** Preliminary considerations-Bilinear transformation method of IIR filter design-design of low pass, 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 III**

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

**Unit IV**

**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 V**

**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:**

After completion of this course the students 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.

**Reference Books:**

1. Digital signal processing-Sanjit K. Mitra-TMH second edition
2. Discrete Time Signal Processing – Alan V.Oppenheim, Ronald W.Shafer - PHI-1996 1st edition-9th reprint
3. Digital Signal Processing and principles, algorithms and Applications – John G.Proakis - PHI –3rd edition-2002
4. Digital Signal Processing – S.Salivahanan, A.Vallavaraj, C. Gnanapriya – TMH - 2nd reprint-2001
5. Theory and Applications of Digital Signal Proceesing-LourensR. Rebinar&Bernold
6. Digital Filter Analysis and Design-Auntonian-TMH

**I-II** **Programmable Logic Controllers & Applications (Elective-IV)** **L / P / Credits 4 / -- / 3**

**Prerequisites:** 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 I:**
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 II:**
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 III:**
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 IV:**
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 V**
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:**
After completion of this course the students 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.

**Reference 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.
3. Introduction to Programmable Logic Controllers- Gary Dunning-Cengage Learning.
4. Programmable Logic Controllers –W.Bolton-Elsevier publisher.

**I-II** **Power Converters & Drives Laboratory** **L / P / Credits**
**-- / 4 / 2**

**Course Educational Objectives:**
To verify the operation of various converters and also their usage in the motor speed control application.

**List of experiments**
1. Gate drive circuits for power MOSFET and IGBT based circuits
2. Buck and Boost DC-DC converters.
3. Buck-Boost DC-DC converters
4. 3-phase A.C. Voltage controller fed to R & RL - load.
5. 3-phase IGBT based PWM Inverter with R & R-L load.
6. Speed control of DC motor drive using 3-phase full Converter.
7. Three phase SVPWM Pulse generation using PIC Micro controller/DSP processor.
8. DSP based V/F Control of 3 phase Induction motor.
9. Vector control based speed control of three phase Induction Motor drive.
10. Speed control of BLDC motor drive using 3-phase VSI.
11. Speed control of PM synchronous motor drive using 3-phase VSI.
12. Speed control of switched reluctance motor.

**Course Outcomes:**
To analyse the working of phase controlled converters, AC voltage controllers, DC-DC converters, and PWM inverters and analyse the speed control operation of power converter fed motors.

**II-I** **Comprehensive Viva-Voce** **L / P / Credits**
**-- / -- / 2**

**Prerequisites:**

**Course Educational Objectives:**

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**Course Outcomes:**

After completion of the course the student will be able to:

**Reference Books :**

**II-I** **Seminar – I** **L / P / Credits**
**-- / -- / 2**

**Prerequisites:**

**Course Educational Objectives:**

-

**Course Outcomes:**

After completion of the course the student will be able to:

**Reference Books :**

**II-I** 

## Project Work - I

**L / P / Credits**
**-- / -- / 16**

**Prerequisites:**

**Course Educational Objectives:**

- 

**Course Outcomes:**

After completion of the course the student will be able to:

**Reference Books :**

II-II

## Seminar – II

L / P / Credits
-- / -- / 2

**Prerequisites:**

**Course Educational Objectives:**

-

**Course Outcomes:**

After completion of the course the student will be able to:

**Reference Books :**

II-II

## Project Work - II

L / P / Credits
-- / -- / 16

**Prerequisites:**

**Course Educational Objectives:**

- 

**Course Outcomes:**

After completion of the course the student will be able to:

**Reference Books :**