**Approved Syllabus for**

# Master of Technology

in

# *POWER & INDUSTRIAL DRIVES*

## From Academic Year 2015-2016

**in**

**BOARD OF STUDIES MEETING HELD**

**on**

**April 25th & 26th, 2015**

**DEPARTMENT OF ELECTRICAL ENGINEERING**

**COLLEGE OF ENGINEERING *(AUTONOMOUS), ANANTHAPURAMU***

**JAWHARLAL NEHRU TECHNOLOGICAL UNIVERSITY ANANTAPUR**

**INFORMATION ON THE COURSE**

**1.0 Details about the Course.**

**1.1 Name of the Course (s)**

| Name of Degree / Diploma | Name of Specialization | Intake (Full / Part time) to be started | Year of Starting (Proposal Admission) | Duration (Total) | Name of Degree & Branch eligible for admission |
|---|---|---|---|---|---|
| M. Tech. | Power & Industrial Drives | 25+7 Sponsored Full time | 2009-2010 | 2 Yrs 4 Semesters | 4 Year Degree Course B. Tech. /B.E. (EEE) |

**1.2 Course Structure (Semester – wise)**

| Name of the Subject | Hrs. / Week | | | |
|---|---|---|---|---|
| | L | T | P | C |
| **I-SEMESTER** | | | | |
| 1. 15D23101 Advanced Power Semiconductor Devices | 4 | - | - | 4 |
| 2. 15D23102 Applications of Power Electronics to Power Systems | 4 | - | - | 4 |
| 3. 15D23103 Machine Modeling & Analysis | 4 | - | - | 4 |
| 4. 15D23104 Solid State DC Drives | 4 | - | - | 4 |
| 6. Elective-I | 4 | - | - | 4 |
| 7. Elective-II | 4 | - | - | 4 |
| 8. 15D23105 Power Electronics and Drives Lab | - | - | 4 | 2 |
| **Electives:** | | | | |
| 15D22101 Modern Control Theory | | | | |
| 15D21104 Power Quality Issues & Improvement | | | | |
| 15D22102 Advanced Digital Signal Processing | | | | |
| 15D22107 Embedded Systems | | | | |
| **II-SEMESTER** | | | | |
| 1. 15D23201 Advanced Power Converters | 4 | - | - | 4 |
| 2. 15D23202 Switched Mode Power Converters | 4 | - | - | 4 |
| 3. 15D23203 Solid State AC Drives | 4 | - | - | 4 |
| 4. 15D22203 Intelligent Algorithms | 4 | - | - | 4 |
| 5. Elective-I | 4 | - | - | 4 |
| 6. Elective – II | 4 | - | - | 4 |
| 7. 15D54201 Research Methodology (Audit Course) | 2 | - | - | 0 |
| 8. 15D23204 Power Electronics and Drives Simulation Lab | - | - | 4 | 2 |
| **Electives:** | | | | |
| 15D22201 Adaptive Control | | | | |
| 15D22206 Process Dynamics and Control | | | | |
| 15D21207 Solar Energy Conversion Systems | | | | |
| 15D21208 Wind Energy Conversion Systems | | | | |
| **III SEMESTER** | | | | |
| 1. 15D23301 Seminar - I | - | - | 4 | 2 |
| **IV SEMESTER** | | | | |
| 1. 15D23401 Seminar – II | - | - | 4 | 2 |
| **III & IV SEMESTER** | | | | |
| 1. 15D23302 Project Work | - | - | - | 44 |

## 15D23101 ADVANCED POWER SEMICONDUCTOR DEVICES

**UNIT-I: Introduction**: Power switching devices overview – Attributes of an ideal switch, application requirements, circuit symbols; Power handling capability – (SOA); Device selection strategy – On-state and switching losses – EMI due to switching - Power diodes - Types, forward and reverse characteristics, switching characteristics – rating.

**UNIT-II: Current Controlled Devices:** BJT's – Construction, static characteristics, switching characteristics; Negative temperature co-efficient and secondary breakdown; Power darlington – Thyristors – Physical and electrical principle underlying operating mode, Two transistor analogy – concept of latching; Gate and switching characteristics; converter grade and inverter grade and other types; series and parallel operation; comparison of BJT and Thyristor – steady state and dynamic models of BJT & Thyristor.

**UNIT-III: Voltage Controlled Devices:**Power MOSFETs and IGBTs – Principle of voltage controlled devices, construction, types, static and switching characteristics, steady state and dynamic models of MOSFET and IGBTs - Basics of GTO, MCT(Mos Controlled Thyristor ), FCT(Field Controlled Thyristor), RCT(Reverse Conducting Thyristor) .

**UNIT-IV: Firing and Protecting Circuits:**Necessity of isolation, pulse transformer, optocopler – Gate drives circuit: SCR, MOSFET, IGBTs and base driving for power BJT. - Over voltage, over current and gate protections; Design of snubbers.

**UNIT-V: Thermal Protection:**Heat transfer – conduction, convection and radiation; Cooling – liquid cooling, vapour – phase cooling; Guidance for hear sink selection – Thermal resistance and impedance -Electrical analogy of thermal components, heat sink types and design – Mounting types

**Text books:**

1. Rashid M. H., "Power Electronics Circuits, Devices and Applications", Prentice Hall India, Third Edition, New Delhi.
2. B.W. Williams 'Power Electronics: Devices, Drivers, Applications and Passive Components, Tata McGraw Hill.

**Reference books:**

1. M. D. Singh and K. B. Khanchandani, "Power Electronics", Tata McGraw Hill.
2. Mohan, Undeland and Robins, "Power Electronics – Concepts, applications and Design, John Wiley and Sons, Singapore.
3. Power electronics by p.s. Bimbhra, Khanna publications.
4. Advanced power electronics converters by Euzeli dos santos, Edison R. da silva.

## 15D23102 APPLICATIONS OF POWER ELECTRONICS TO POWER SYSTEMS

**UNIT I: General System considerations and FACTS:** Transmission Interconnections, Flow of Power in an AC System, Power Flow and Dynamic Stability Considerations of a Transmission Interconnection, principles of series and shunt compensation, Basic Types of FACTS Controllers, Benefits from FACTS, Application of FACTS.

**UNIT II: Shunt Compensators:** Objectives of Shunt Compensation, Midpoint Voltage Regulation for Line Segmentation, End of Line Voltage Support to Prevent Voltage Instability, improvement of Transient Stability, Power Oscillation Damping, Static Var Compensators, SVC and STATCOM, The Regulation Slope, Transfer Function and dynamic Performance, Transient Stability, Enhancement and Power Oscillation Damping

**UNIT III: Series Compensators:** Objectives of Series Compensation, concept of series capacitive compensation, voltage stability, improvement of transient stability, power oscillation damping, GTO thyristor controlled series capacitor, Thyristor controlled series capacitor, SSSC.

**UNIT IV: Combined Compensators:** Introduction, Unified power flow controller, basic operating principles, independent real and reactive power flow control, and control structure, basic control system for P and Q control.

**UNIT V: Mitigation of Harmonics:** Power quality problems, harmonics, harmonic creating loads, harmonic power flow, and mitigation of harmonics, filters, passive filters, active filters, shunt, series and hybrid filters.

**Text books:**

1. Narain G. Hingorani, Laszlo Gyugyi, Understanding FACTS, IEEE press
2. Roger. C. Dugan, Mark. F. McGranagham, Surya Santoso, H.Wayne Beaty, Electrical Power Systems Quality, McGraw Hill,2003

**Suggested Reading:**

1. Y.H.Song, A.T.Johns, Flexible A.C.Transmission System, IEE, London, 1999

## 15D23103 MACHINE MODELING & ANALYSIS

**UNIT -I:_Basic Principles for Machine Analysis:** Magnetically Coupled Circuits, Machine Windings and Air-Gap MMF, Winding Inductances and Voltage Equations.
**Modeling And Analysis Of DC Machines**:
Elementary DC Machine, Voltage and Torque Equations, Types of DC Machines, Permanent and Shunt DC Motors, Time-Domain and State-Equations,

**UNIT-II:_Reference Frame Theory**: Introduction to Transformations, Equations of Transformations, Change of Variables, and Transformation to an Arbitrary Reference Frame, Commonly used Reference Frames, Transformation between Reference Frames, Steady-State Phasor Relationships and Voltage Equations

**UNIT-III: Modeling & Dynamic Analysis of Three Phase Induction Machines:** Voltage and Torque Equations in Machine Variables, Voltage and Torque Equations in Arbitrary Reference Frame, Steady-State Analysis and its Operation.
Free Acceleration Characteristics viewed from Various Reference Frames, Dynamic Performance during Sudden Changes in Load Torque, Dynamic Performance during A Three-Phase Fault at the Machine Terminals

**UNIT-IV:_Modeling & Dynamic Analysis of Synchronous Machine:** Voltage and Torque Equations in Machine Variables, Voltage Equations in Arbitrary and Rotor Reference Frame, Torque Equations in Substitute Variable, Steady-State Analysis and its Operation.
Dynamic Performance of Synchronous Machine, Three-Phase Fault, Comparison of Actual and Approximate Transient Torque Characteristics, Equal Area Criteria.

**UNIT -V**: **Modeling of Special Machines:** Modeling of Permanent Magnet Brushless DC Motor Operating principle – Mathematical modeling of PM Brushless DC motor - PMDC Motor Drive Scheme.

**Text books**

**1.** Krause, Wasynczuk, Sudhoff, **Analysis of Electric Machinery and Drive Systems**: 2nd Edition, Wiley Interscience Publications, 2002.

2. P. C. Krause, Analysis of Electric Machinery, McGraw Hill-1980

## 15D23104 SOLID STATE DC DRIVES

**UNIT-I: DC MOTORS FUNDAMENTALS AND MECHANICAL SYSTEMS:** DC motor- Types, induced emf, speed-torque relations; Speed control – Armature and field speed control; Ward Leonard control – Constant torque and constant horse power operation - Introduction to high speed drives and modern drives.
Characteristics of mechanical system – dynamic equations, components of torque, types of load; Requirements of drives characteristics – multi-quadrant operation; Drive elements, types of motor duty and selection of motor rating.

**UNIT-II: CONVERTER CONTROL:** Principle of phase control – Fundamental relations; Analysis of series and separately excited DC motor with single-phase and three-phase converters – waveforms, performance parameters, performance characteristics. Continuous and discontinuous armature current operations; Current ripple and its effect on performance; Operation with freewheeling diode; Implementation of braking schemes; Drive employing dual converter.

**UNIT-III : CHOPPER CONTROL:** Introduction to time ratio control and frequency modulation; Class A, B, C, D and E chopper controlled DC motor – performance analysis, multi-quadrant control – Chopper based implementation of braking schemes; Multi-phase chopper; Related problems.

**UNIT-IV: CLOSED LOOP CONTROL:** Modeling of drive elements – Equivalent circuit, transfer function of self, separately excited DC motors; Linear Transfer function model of power converters; Sensing and feeds back elements - Closed loop speed control – current and speed loops, P, PI and PID controllers – response comparison. Simulation of converter and chopper fed d.c drive.

**UNIT-V: DIGITAL CONTROL OF D.C DRIVE:** Phase Locked Loop and micro-computer control of DC drives – Program flow chart for constant horse power and load disturbed operations; Speed detection and gate firing.

**TEXT BOOKS**

1. Gopal K Dubey, “Power Semiconductor controlled Drives”, Prentice Hall Inc., New Yersy, 1989.
2. R.Krishnan, “Electric Motor Drives – Modeling, Analysis and Control”, Prentice-Hall of India Pvt. Ltd., New Delhi, 2003.

**REFERENCES**

1.Gobal K.Dubey, “Fundamentals of Electrical Drives”, Narosal Publishing House, New Delhi, 2001.
2.Bimal K.Bose “Modern Power Electronics and AC Drives”, Pearson Education (Singapore) Pte. Ltd., New Delhi, 2003.
3.Vedam Subramanyam, “Electric Drives – Concepts and Applications”, Tata McGraw-Hill publishing company Ltd., New Delhi, 2002.
4.P.C Sen “Thyristor DC Drives”, John wiely and sons, New York, 1981
**5.** Power Electronics By M. D. Singh

# 15D23105 POWER ELECTRONICS AND DRIVES LAB

**List of Experiments**

1. Study of DSP board and Generation of 3-phase Pulse Width Modulated (PWM) Sequence
2. Generation of SINE-Triangular PWM for single/ three-phase inverter system
3. Generation of Space-vector modulation PWM for single/ three-phase inverter system
4. Speed control of inverter fed induction motor using sine-triangular PWM method.
5. Speed control of inverter fed induction motor using space-vector PWM method.
6. Speed control of chopper fed separately excited dc motor (four quadrant operation).
7. Closed loop speed control of BLDC motor/ PMSM/ SRM

## XILINX Based

1. (a) Demonstration about FPGA processor, its importance in the advanced controller era :: Understanding Spartan-3E diligent board.

(b) Demonstration about Xilinx-9i based Electronic Distribution and Automation (EDA) Software, HDL languages (Verilog & VHDL) and Synthesis.

**Note: At least two problems may be implemented from the following**

2. Design the following Simple logic circuits in Xilinx-9i EDA Software using Verilog / VHDL language and obtain its Synthesis.

   (i) AND, OR logic gates and (ii) Half Adder.

3. Design of Top-Bottom level (Instantiation) modular circuits of the following in Xilinx-9i EDA Software using Verilog/VHDL language and obtain its Synthesis.

   (i) Instantiate AND-AND logic to OR gate.
   (ii) Instantiate two Half Adders to obtain Full Adder.

4. Generate single pulse PWM output by writing counter program in Xilinx EDA software, obtain its Synthesis and timing simulation.
5. Generate multi pulse PWM output by writing counter program in Xilinx EDA software, obtain its Synthesis and timing simulation.
6. Instantiate DCM)/UART write a user constraint file to assign pin packages and implement Spartan-3E diligent board observe LED outputs
7. Design digital logic circuit to obtain stepper motor control and implement in Spartan-3E diligent board.

## 15D22101 MODERN CONTROL THEORY

**Unit I**

Fields, Vectors, and vector spaces; State space representation, state equations for dynamic systems, solution of state equations; State transition matrix – Properties of state transition matrix; evaluation. Fadeeva algorithm for conversion from state space to transfer function, Linearization of non-linear models

**Unit II**

Non uniqueness of state model, Similarity transformation, Invariance of system properties. Controllability – necessary and sufficient condition - Pole assignment using State feedback – Ackerman's formula for feedback gain determination; Observability. Duality. Effect of state feedback on controllability and observability. Controllable subspace – decomposition of state into controllable and uncontrollable components.

**Unit III**

Design of full order observer – Bass Gura algorithm. The separation principle - Combined observer – controller compensator. Design of reduced order observer. Unobservable subspace – decomposition of state into observable and unobservable components – Canonical decomposition theorem.

**Unit IV**

Reducibility – realization of transfer function matrices. Model decomposition and decoupling by state feedback. Design of robust control system for asymptotic tracking and disturbance rejection using State variable equations. Transfer function interpretations – transfer function form of observer and state estimate feedback. State space interpretation of internal model principle.

**Unit V**

Discrete time linear state regulator – Algorithm for the solution, Use of observer in implementing the control law. Continuous time linear state regulator – Matrix Riccati equation. Time invariant linear state regulator – the reduced matrix Riccati equation - An iterative method to solve the reduced matrix Riccati equation. Suboptimal linear regulator.

**Text Books**:

1. Modern Control Engineering, Katsuhiko Ogata, 5th Edition, Prentice Hall India, 1997
2. Modern Control System Theory, M. Gopal, Revised 2nd Edition, New Age International Publishers, 2005.

**References:**

1. Linear Systems, Thomas Kailath, Perntice Hall, 1980.
2. Control System Design, Graham C. Goodwin, StefanF. Graebe and Mario E. Salgado, Pearson Education, 2000.
3. Linear System Theory and Design, Chi-Tsong Chen, OXFORD University Press.
4. Richard C. Dorf and Robert H. Bishop, Modern Control Systems, 11th Edition, Pearson Edu India, 2009.

## 15D21104 POWER QUALITY ISSUES & IMPROVEMENT

### UNIT I: INTRODUCTION TO POWER QUALITY

Definition of Power Quality - Power Quality Progression - Power Quality Terminology - Power Quality Issues - Susceptibility Criteria - Responsibilities of Power Suppliers and Users - Power Quality Standards.

### UNIT II: POWER FREQUENCY DISTURBANCE & TRANSIENTS

Introduction to Power Frequency Disturbance - Common Power Frequency Disturbances - Cures for Low Frequency Disturbances - Voltage Tolerance Criteria - ITIC Graph - Introduction to Transients - Transient System Model - Examples of Transient Models and Their Response - Power System Transient Modeling - Types and Causes of Transients - Examples of Transient Waveforms.

### UNIT III: HARMONICS & ELECTROMAGNETIC INTERFERENCE (EMI)

Definition of Harmonics - Harmonic Number (h) - Odd and Even Order Harmonics - Harmonic Phase Rotation and Phase Angle - Voltage and Current Harmonics - Individual and Total Harmonic Distortion - Harmonic Signatures - Effect of Harmonics On Power System Devices - Guidelines For Harmonic Voltage and Current Limitation - Harmonic Current Mitigation - Introduction to EMI - Frequency Classification - Electrical Fields - Magnetic Fields - EMI Terminology - Power Frequency Fields - High Frequency Interference - EMI Susceptibility - EMI Mitigation - Cable Shielding - Health Concerns of EMI.

### UNIT IV: GROUNDING AND BONDING

Introduction to Grounding and Bonding - Shock and Fire Hazards - NEC Grounding Requirements - Essentials of a Grounded System - Ground Electrodes - Earth Resistance Tests - Earth Ground Grid Systems - Power Ground System - Signal Reference Ground (SRG) - SRG Methods - Single and Multipoint Grounding - Ground Loops - Electrochemical Reaction - Examples of Grounding Anomalies.

### UNIT V: MEASURING AND SOLVING POWER QUALITY PROBLEMS

Introduction to Power Quality Measurements - Power Quality Measurement Devices - Power Quality Measurements - Test Locations - Test Duration - Instrument Setup - Instrument Guidelines

### TEXT BOOKS:

1. Power quality by C. Sankaran, CRC Press
2. Electrical Power Systems Quality, Roger C. Dugan, Mark F. McGranaghan, Surya Santoso, H.Wayne Beaty, 2nd Edition, TMH Education Pvt. Ptd.

### REFERENCE BOOKS:

1. Understanding Power quality problems by Math H. J. Bollen IEEE Press
2. Power quality enhancement using custom power devices by Arindam Ghosh,Gerard Ledwich,Kluwer academic publishers

# 15D22102 ADVANCED DIGITAL SIGNAL PROCESSING

**UNIT-I:**

Short introduction, Analog to digital and Digital to Analog conversion, sampled and Hold circuit, Continuous time Fourier Transforms. Discrete-time signals and systems, Discrete-time Fourier transform- its properties and applications, Fast Fourier Transform (in time-domain and Frequency domain) , IDFT and its properties.

**UNIT-II: z- Transforms**

Definition and properties, Rational z-transforms, Region of convergence of a rational z- Transform, The inverse z- Transform, z-Transform properties, Computation of the convolution sum of finite-length sequences, The transfer function.

**Digital Filter Structures:** Block Diagram representation, Equivalent structures, Basic FIR Digital Filter structures, Basic IIR Digital Filter structures, Realization of Basic structures using MATLAB, All pass filters, Computational complexity of Digital filter structures.

**UNIT III**: **IIR Digital Filter Design:**

Preliminary considerations, Bilinear transformation method of IIR Filter design, Design of low pass IIR Digital filters, Design of High pass, Band pass and band stop IIR digital filters, Spectral Transformations of IIR filter, IIR digital filter design using MATLAB, Computer aided design of IIR digital filters.

**UNIT IV:FIR Digital Filter Design:**

Preliminary considerations, FIR filter design based on windowed Fourier series, Computer aided design of Equiripple Linear phase FIR filters, Design of Minimum phase FIR filters, FIR digital filter design using MATLAB, Design of computationally efficient FIR digital filters.

**UNIT V: Analysis of Finite word length effects**:

The quantization process and errors, quantization of Fixed point numbers, Quantization of floating point numbers, Analysis of coefficient quantization effects, Analysis of arithmetic round off errors, Low sensitivity digital filters, Reduction of product round off errors using error feedback, Round off errors in FFT algorithms. The basic sample rate alteration devices, Multi rate structures for sampling rate conversion, Multistage design of decimator and interpolator, The Polyphase decomposition, Arbitrary-rate sampling rate converter, Nyquist Filters and some applications of digital signal processing.

**Text Books:**

1. S.K. Mitra**, Digital Signal Processing**-, Tata McGraw-Hill, Third Edition, 2006.
2. B.P. Lathi, **Principle of Signal Processing and Linear Systems**-, Oxford International Student Version, 2009
3. M. Mondal and A Asif, **Continuous and Discrete Time Signals and Systems**, Cambridge, 2007

**References:**

1. Li Tan, **Digital Signal Processing- Fundamentals and Applications**-, Indian reprint, Elsevier, 2008.
2. Alan V. Oppenheim, Ronald W. Schafer, and John R.Buck, **Discrete- Time Signal Processing-**, Pearson Edu, 2008.

## 15D22107 EMBEDDED SYSTEMS

**UNIT- I Embedded Systems: Processor & Memory Organization**
Embedded System, types of Embedded System, Requirements of Embedded System, Issues in Embedded software development, Applications, Structural units in a processor, Processor selection, Memory devices, Memory selection, Memory Allocation & Map; Interfacing

**UNIT-II: Devices, Device Drivers & Buses for Device Networks**
I/O devices, Timer & Counter devices, Serial Communication, Communication between devices using different buses, Device drives, Parallel and serial port device drives in a system, Interrupt servicing mechanism, context and periods for context switching, Deadline and Interrupt Latency.

**UNIT-III: Real Time Operating Systems**
Operating System Services, I/O Subsystems, Network Operating Systems, Real-Time and Embedded System Operating Systems, Interrupt Routines and Handling of Interrupt Source Call in RTOS, RTOS task scheduling Models, Interrupt Latency and Response Times of the Tasks, Performance Metric in Scheduling Models for different Tasks, IEEE standard POSIX 1003.1b Functions for standardization of RTOS and Inter_Task Communication Functions, List of basic actions in a Preemptive Scheduler and Expected Times taken at a processor, Fifteen-point Strategy for Synchronization between the Processes, ISRs, OS Functions and Tasks for Resource Management, OS Security Issues, Mobile OS.

**UNIT-IV: Hardware-Software Co-Design in an Embedded System**
Embedded System Project Management, Embedded system design and co-design issues in system development process, design cycle in development phase for Embedded System, Uses of its Emulator and In-Circuit Emulator (ICE), Use of Software tools for development of an Embedded System, Use of scopes and Logic Analyzers for system Hardware tests, Issues in Embedded system design

**UNIT-V: Applications**
Embedded System Design for: An Adaptive Cruise Control System in a car, Smart Card, Digital Clock, Battery-operated Smartcard Reader, Automated Meter Reading (AMR) System, Digital Camera

**TEXT BOOKS:**

1. Raj Kamal, “Embedded Systems : Architecture, Programming and Design”, Tata McGraw Hill, 2005
2. Shibu. K. V, “Introduction to Embedded Systems”, Tata McGraw Hill, 2009

## 15D23201 ADVANCED POWER CONVERTERS

**UNIT-I: PWM Inverters:** Principle of Operation – Performance Parameters – Single Phase Bridge Inverter – Output Voltage and Current With R, R-L & R-L-C Loads – Voltage Control of Single Phase Inverters – Advanced Modulation Techniques for Improved Performance –Numerical Problems.

Three Phase Inverters –180 Degree Condition –120 Degree Conduction – Analysis – Output Voltage and Current With R, R-L & R-L-C Loads – Voltage Control of Three Phase Inverters – Comparison of PWM Techniques – Harmonic Reductions – Current Source Inverter – Variable DC Link Inverter – Buck and Boost Inverter – Inverter Circuit Design – Applications – Numerical Problems.

**UNIT-II: Resonant Pulse Inverters:** Series Resonant Inverters – Analysis with Unidirectional Switches & Bidirectional Switches – Evaluation of Currents and Voltages – Frequency Response of Series Resonant Inverters – Series Loaded Inverter –Parallel Loaded Inverter –Series and Parallel Loaded Inverters – Parallel Resonant Inverters – Voltage Control of Resonant Inverters – Class E Resonant Inverter & Class E Resonant Rectifier – Numerical Problems.

Resonant Converters – Zero Current Switching Resonant Converters – L Type– M Type – Zero Voltage Switching Resonant Converters – Comparison Between ZCS And ZVS – Resonant Converters – Two Quadrant ZVS Resonant Converters – Resonant DC-Link Inverters – Numerical Problems.

**UNIT-III: Multilevel Inverters**

Multilevel Concept – Types of Multilevel Inverters – Diode Clamped Multilevel Inverter – Improved Diode Clamped Inverter – Flying Capacitors Multilevel Inverter – Cascaded Multilevel Inverter– Principle Of Operation – Main Features– Applications – Reactive Power Compensation, Back to Back Intertie System, Adjustable Drives– Switching Device Currents – DC Link Capacitor Voltage Balancing – Features of Multilevel Inverters –Comparisons of Multilevel Converters – Numerical Problems.

**UNIT-IV: DC Power Supplies :**DC Power Supplies – Types – Switched Mode DC Power Supplies – Fly Back Converter –Forward Converter – Push-Pull Converter – Half Bridge Converter – Full Bridge Converter –Resonant DC Power Supplies – Bidirectional Power Supplies – Applications – Numerical Problems.

**UNIT-V: AC Power Supplies:** AC Power Supplies – Types – Switched Mode Ac Power Supplies – Resonant AC Power Supplies – Bidirectional Ac Power Supplies – Multistage Conversions – Control Circuits – Power Line Disturbances – Power Conditioners – Uninterruptible Power Supplies – Applications – Numerical Problems.

**TEXT BOOKS:**

1. Power Electronics – Mohammed H. Rashid – Pearson Education – Third Edition.
2. Power Electronics – Ned Mohan, Tore M. Undeland and William P. Robbins – John Wiley and Sons – Second Edition

## 15D23202 SWITCHED MODE POWER CONVERTERS

**UNIT –I DC-DC Converters:** Buck Converter, Boost Converter, Buck-boost converter, Cuk converter – Steady-State Analysis, Duty Ratio, Volt-Sec Balance and Voltage Gain, Average Voltage and Current Expressions, Ripple Current and Voltage Expressions, Finding Performance Parameters, Numerical problems, Comparison of Converters, Multi Output Boost Converters, Diode Rectifier fed Boost Converter, Chopper Circuit Design.

**UNIT – II Dynamic Analysis of Dc-Dc Converters:** Formulation of averaged Circuit Models of Buck, Boost and buck-boost Converters, Small Signal Analysis and Linearization– Need for Small Signal Models, Obtaining Models, Generalizing the Process.
Introduction to Control Design and Control Design based on Linearization - Transfer Functions, Compensation and Filtering, Numerical problems. Voltage Mode, Current Mode and Hysteresis Controls for DC – DC Converters.

**UNIT – III Single-Switch Isolated Converters:** Requirement for Isolation in the Switch-Mode Converters, Transformer Connection, Forward and Fly Back Converters, Power Circuit and Steady-State Analysis – Finding Performance Parameters - Numerical Problems
**Push-Pull Converters:** Power Circuit and Steady-State Analysis, Utilization of Magnetic Circuits in Single Switch and Push-Pull Topologies - Finding Performance Parameters - Numerical Problems.

**UNIT – IV Isolated Bridge Converters:** Half Bridge and Full-Bridge Converters, Power Circuit and Steady-State Analysis, Utilization of Magnetic Circuits and Comparison with Previous Topologies, Numerical Problems.
Configurations of Resonant DC Power Supplies – Bidirectional Power Supplies – Switch Mode AC Power Supplies – Resonant Ac Power Supplies – Bidirectional AC Power Supplies - Finding Performance Parameters – Numerical Problems.

**UNIT – V Resonant Converters & Quasi-Resonant Converters:**
Classification of Resonant Converters-Basic Resonant Circuits - Series Resonant Circuit - Parallel Resonant Circuits - Resonant Switches, Numerical Problems.
Concept of Zero Voltage Switching, Concept of Zero Current Switching – Principle Of Operation, Analysis of M-Type And L-Type Buck or Boost Converters, Numerical Problems.

**TEXT BOOKS:**

1. Robert Erickson and Dragon Maksivimovic, **Fundamentals of Power Electronics**, Springer Publications.
2. Issa Batarseh**, Fundamentals of Power Electronics,** John Wiley Publications, 2009.
3. M. H. Rashid, **Power Electronics Circuits, Devices and Applications**, Prentice Hall ,2003

**REFERENCE BOOKS:**

1. Philip T.Krein **Elements of Power Electronics** - Oxford University Press, 1997.
2. L. Umanand **Power Electronics,** Tata Mc-Graw Hill, 2004.
3. Robert Erickson and Dragon Maksivimovic, **Fundamentals of Power Electronics**, Springer Publications.

## 15D23203 SOLID STATE AC DRIVES

**UNIT-I: Induction Motor- An Overview**

Review of Steady-State Operation of Induction Motor, Equivalent Circuit Analysis, Torque-Speed Characteristics.

**Phase Controlled Induction Motor Drive**

Stator Voltage Control of Induction Motor, Phase-Controlled Converter Fed Induction Motor, Power Circuit and Gating, Reversible Phase-Controlled Induction Motor Drive, Torque-Speed Characteristics.

**UNIT-II: Voltage Source Inverter Fed Induction Motor Drive**

Stator Voltage and Frequency Control of Induction Motor, Torque-Speed Characteristic Static Frequency Changers, PWM Inverter Fed Induction Motor Drive, Variable-Voltage Variable-Frequency Operation of Induction Motor, Constant E/f And V/f Control Schemes, Slip Regulation.

**Current Source Inverter Fed Induction Motor Drive**

Stator Current and Frequency Control of Induction Motor, Auto Sequentially Commutated Inverter (ASCI), Power Circuit, Commutation, Phase Sequence Reversal, Regeneration, Steady-State Performance.

**UNIT-III: Rotor Side Control of Slip-Ring Induction Motor**

Slip-Power Recovery Schemes, Steady-State Analysis- Range of Slip, Equivalent Circuit, Performance Characteristics; Rating of Converters.

**Vector Control of Induction Motor**

Principles of Vector Control, Direct Vector Control, Derivation of Indirect Vector Control, Implementation – Block Diagram, Estimation of Flux, Flux Weakening Operation.

**UNIT-IV: Control of Synchronous Motor Drives**

Synchronous Motor and Its Characteristics- Control Strategies-Constant Torque Angle Control-Power Factor Control, Constant Flux Control, Flux Weakening Operation, Load Commutated Inverter Fed Synchronous Motor Drive, Motoring and Regeneration, Phasor Diagrams.

**Unit-V: PMSM and BLDC Drives**

Characteristics of Permanent Magnet, Synchronous Machines With Permanent Magnet, Vector Control of PMSM- Motor Model and Control Scheme, Constant Torque Angle Control, Constant Mutual Flux Linkages, Unity PF Control. Modeling of PM Brushless Dc Motor, Drive Scheme, Commutation Torque Ripple, Phase Advancing.

**TEXT BOOK:**

1.R. Krishnan, **Electric Motor Drives Modeling, Analysis & control**, Pearson Education, 2001.

**REFERENCE BOOKS:**

1. B. K. Bose **Modern Power Electronics and AC Drives**, Pearson Publications-2001.
2. MD Murphy & FG Turn Bull, Pergaman press, **Power Electronics control of AC motors** 1$^{st}$edition-1998.
3. G.K. Dubey **Fundamentals of Electrical Drives** Narosa Publications -1995.

## 15D22203 INTELLIGENT ALGORITHMS

**UNIT I:**
Introduction and motivation. Approaches to intelligent control. Architecture for intelligent control. Symbolic reasoning system, rule - based systems, the AI approach. Knowledge representation. Expert systems. Data Pre - Processing: Scaling, Fourier transformation, principal - component analysis and wavelet transformations.

**UNIT II**
Concept of Artificial Neural Networks and its basic mathematical model, McCulloch - Pitts neuron model, simple perceptron, Adaline and Madaline, Feed - forward Multilayer Perceptron. Learning and Training the neural network. Networks: Hopfield network, Self - organizing network and Recurrent network. Neural Network based controller, Case studies: Identification and control of linear and nonlinear dynamic systems using Matlab / Neural Network toolbox.

**UNIT III**
Genetic Algorithm: Basic concept of Genetic algorithm and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using genetic algorithm. Concept on some other than GA search techniques like tabu search and ant - colony search techniques for solving optimization problems.

**UNIT IV**
Introduction to crisp sets and fuzzy sets, basic fuzzy set operation and approximate reasoning. Introduction to Fuzzy logic modeling and control of a system. Fuzzification, inference and defuzzification. Fuzzy knowledge and rule bases.

**UNIT V**
Fuzzy modeling and control schemes for nonlinear systems. Self - organizing fuzzy logic control. Implementation of fuzzy logic controller using Matlab fuzzy - logic toolbox. Stability analysis of fuzzy control systems. Intelligent Control for SISO/MIMO Nonlinear Systems. Model Based Multivariable Fuzzy Controller.

**TEXT BOOKS**

1. Simon Haykins, Neural Networks: A comprehensive Foundation, Pearson Edition, 2003.
2. T.J.Ross, Fuzzy logic with Fuzzy Applications, Mc Graw Hill Inc, 1997.
3. David E Goldberg, Genetic Algorithms.

**REFERENCES**

1. M.T.Hagan, H. B. Demuth and M. Beale, Neural Network Design, Indian reprint, 2008.
2. Fredric M.Ham and Ivica Kostanic, Principles of Neurocomputing for science and Engineering, McGraw Hill, 2001.
3. N.K. Bose and P.Liang, Neural Network Fundamentals with Graphs, Algorithms and Applications, Mc - Graw Hill, Inc. 1996.
4. Yung C. Shin and Chengying Xu, Intelligent System - Modeling, Optimization and Control, CRC Press, 2009.
5. N.K.Sinha and Madan M Gupta, Soft computing & Intelligent Systems - Theory & Applications, Indian Edition, Elsevier, 2007.
6. John Yen and Reza Langari, Fuzzy logic Intelligence, Control, and Information, Pearson Education, Indian Edition, 2003.
7. Witold Pedrycz, Fuzzy Control and Fuzzy Systms, Overseas Press, Indian Edition, 2008.

# 15D54201 RESEARCH METHODOLOGY

## (Audit Course)

## UNIT I

Meaning of Research – Objectives of Research – Types of Research – Research Approaches – Guidelines for Selecting and Defining a Research Problem – research Design – Concepts related to Research Design – Basic Principles of Experimental Design.

## UNIT II

Sampling Design – steps in Sampling Design –Characteristics of a Good Sample Design – Random Sampling Design.

Measurement and Scaling Techniques-Errors in Measurement – Tests of Sound Measurement – Scaling and Scale Construction Techniques – Time Series Analysis – Interpolation and Extrapolation.

Data Collection Methods – Primary Data – Secondary data – Questionnaire Survey and Interviews.

## UNIT III

Correlation and Regression Analysis – Method of Least Squares – Regression vs Correlation – Correlation vs Determination – Types of Correlations and Their Applications

## UNIT IV

Statistical Inference: Tests of Hypothesis – Parametric vs Non-parametric Tests – Hypothesis Testing Procedure – Sampling Theory – Sampling Distribution – Chi-square Test – Analysis of variance and Co-variance – Multi-variate Analysis.

## UNIT V

Report Writing and Professional Ethics: Interpretation of Data – Report Writing – Layout of a Research Paper – Techniques of Interpretation- Making Scientific Presentations in Conferences and Seminars – Professional Ethics in Research.

**Text books:**

1. **Research Methodology:Methods and Techniques – C.R.Kothari, 2nd Edition,New Age International Publishers.**
2. **Research Methodology: A Step by Step Guide for Beginners- Ranjit Kumar, Sage Publications (Available as pdf on internet)**
3. **Research Methodology and Statistical Tools – P.Narayana Reddy and G.V.R.K.Acharyulu, 1st Edition,Excel Books,New Delhi.**

**REFERENCES:**

1. **Scientists must Write - Robert Barrass (Available as pdf on internet)**
2. **Crafting Your Research Future –Charles X. Ling and Quiang Yang (Available as pdf on internet)**

# 15D23204 POWER ELECTRONICS AND DRIVES SIMULATION LAB

**List of Experiments**

1. **Simulation of 1-phase/ 3-phase IGBT based bridge inverter circuits with R, R-L loads.**
2. **Simulation of 3-phase bridge inverter.**
3. **Simulation of 1-phase/3-phase thyristorized converters (semi, full converter)**
4. **Simulation of 3-phase converters.**
5. **Simulation of speed control of separately excited DC motor.**
6. **Simulation of Closed loop speed control of BLDC motor.**
7. **Simulation of DC-DC converters (Buck, boost and Buck-boost converters).**
8. **Simulation of two-level and three-level inverter with sinusoidal PWM.**
9. **Simulation of VSI fed Induction motor (square wave and PWM inverters).**
10. **Simulation of induction motor with open loop constant V/F control.**
11. **Simulation of induction motor with indirect vector control.**
12. **Simulation of PMSM.**

**(Simulation software tools: Matlab/Simulink/PSPICE/PSIM)**

## **15D22201** ADAPTIVE CONTROL

**UNIT – I**

Introduction, Block Diagram of an Adaptive System, Effects of Process Variations on System Performance, Types of Adaptive Schemes, Formulation of The Adaptive Control Problem, Abuses of Adaptive Control, Least Squares Method and Regression Models for Parameter Estimation – Theorems, Estimating Parameters in Models of Dynamic Systems, The Finite Impulse Response Model, The Transfer Function Model, and The Stochastic Model.

**UNIT – II**

Block Diagram of Deterministic Self Tuning Regulator (STR), Pole Placement Design – Process Model, Model Following, Causality Conditions. Indirect STRs – Estimation, Continuous - Time STRs, Direct STRs – Minimum Phase Systems, Adaptive Control Algorithm, Feed Forward Control, Non Minimum Phase Systems – Adaptive Control Algorithm, Algorithm For Hybrid STR.

**UNIT – III**

Design of Minimum Variance and Moving - Average Controllers, Stochastic STR – Indirect STR, Algorithm for Basic STR, Theorems on Asymptotic Properties. Unification of Direct STRs, Generalized Direct Self Tuning Algorithm, Self Tuning Feed Forward Control. Linear Quadratic STR – Theorems on LQG Control, Algorithms for Indirect LQG – STRs Based on Spectral Factorization and Riccati Equation.

**UNIT –IV**

Model Reference Adaptive System (MRAS), The MIT Rule, Block Diagram of an MRAS for adjustment of Feed Forward Gain based on MIT Rule. Adaptation Gain – Methods for determination. Design of MRAS using Lyapunov Theory – Block Diagram of an MRAS based on Lyapunov Theory for a First Order System. Proof of The Kalman – Yakubovich Lemma, Adjustment Rules for Adaptive Systems, Relation between MRAS and STR.

**UNIT – V**

Gain Scheduling – Principle, Block Diagram, Design of Gain Scheduling Controllers, Nonlinear Transformations, Block Schematic of a Controller based on Nonlinear Transformations. Application of Gain Scheduling for Ship Steering, Flight Control. Self Oscillating Adaptive System (SOAS) – Principle, Block Diagram, Properties of The Basic SOAS, Procedure for Design of SOAS. Industrial Adaptive Controllers and applications.

**Text books**

1. K.J.Astrom and Bjorn Wittenmark, Adaptive control, Pearson Edu., 2nd Edn.
2. Sankar Sastry, Adaptive control.

**References**

1. V.V.Chalam, Adaptive Control System - Techniques & Applications, Marcel Dekker Inc.
2. Miskhin and Braun, Adaptive control systems, MC Graw Hill
3. Karl Johan Åström, Graham Clifford Goodwin, P. R. Kumar, Adaptive Control, Filtering and Signal Processing
4. G.C. Goodwin, Adaptive control.
5. Narendra and Anna Swamy, Stable Adaptive Systems.

## 15D22206 PROCESS DYNAMICS AND CONTROL

**UNIT I:**

Introduction to Process Control, Representative Process Control Problems, Illustrative Example-A Blending process, Classification of Control Strategies, Hierarchy of Process Control activities, Dynamic versus Steady - state Models, The rationale of Dynamic Process models, General Modeling Principles, Dynamic model of CSTR, Degrees of freedom analysis, Linearization of Non-linear models. Processes with time delays, Approximation of Higher - Order transfer functions, Interacting and Non interacting Processes, Multiple - Input, Multiple - Output (MIMO) Processes.

**UNIT II:**

Basic Control modes, Features of PID Controllers, Typical process responses with Feedback control, Digital versions of PID Controllers, Transducers and Transmitters, Final Control elements, Accuracy in Instrumentation, Guidelines for selection of Controlled, Manipulated and Measured variables, Process safety and Process Control, Block diagram representation of Blending process composition control system, General stability criterion, Routh Stability criterion for time delay systems, Direct substitution method.

**UNIT III:**

Performance Criteria for Closed - Loop Systems, Model - based design methods - Direct Synthesis Method, Internal Model Control, Controller tuning relations, Controllers with two degrees of freedom, Online controller tuning, trial and error tuning, Continuous Cycling Method, Relay auto tuning, Process Reaction Curve Method, Guidelines for Common Control Loops, troubleshooting Control Loops.

**UNIT IV:**

Introduction to Feed forward Control, Ratio Control, Feed forward Controller Design based on Steady - State Models, Controller Design based on Dynamic Models, Tuning Feed forward Controllers, Configurations for Feed forward - Feedback Control, Cascade control, Design considerations for cascade control, Time delay compensation, Block diagram of the Smith predictor, Inferential control, Selective control/Override systems.

**UNIT V:**

Multi loop and multivariable control: Process Interactions and Control Loop Interactions, Pairing of Controlled and Manipulated Variables, Bristols RGA method, Calculation of the RGA, Methods for obtaining the steady state gain matrix, Measure of Process Interactions and Pairing recommendations, Dynamic considerations, Extensions of the RGA analysis, Singular value analysis, Selection of manipulated variables and Controlled variables, Tuning of multi loop PID Control systems, Decoupling and multi variable control strategies, Strategies for Reducing Control Loop Interactions.

**TEXT BOOKS:**

1. Dale E. Seborg, University of California, Santa Barbara, Thomas F. Edgar, University of Texas at Austin, Duncan A. Mellichamp, University of California, Santa Barbara, Process Dynamics and Control, John Wiley & Sons, 1989.
2. Dale E. Seborg, University of California, Santa Barbara, Thomas F. Edgar, University of Texas at Austin, Duncan A. Mellichamp, University of California, Santa Barbara, Process Dynamics and Control, John Wiley & Sons, 2nd Edition, 2004.

**REFERENCES:**

1. Brian Roffel, Ben Betlem, Process Dynamics and Control Modeling for Control and Prediction, John Wiley & Sons Ltd., 2007.

## 15D21207 SOLAR ENERGY CONVERSION SYSTEMS

**UNIT-I: SOLAR CELL FUNDAMENTALS**

Place of PV in world energy scenario – need for sustainable energy sources – current status of Renewable energy sources – place of photovoltaic in Energy supply – solar radiation – the sun and earth movement – angle of sunrays on solar collectors – sun tracking – estimating solar radiation empirically – measurement of solar radiation - Fundamentals of semiconductors – charge carriers and their motion in semiconductor – P-N Junction Diode – an introduction to solar cells.

**UNIT-II: DESIGN OF SOLAR CELLS**

Upper limits of cell parameters – short circuit current, open circuit voltage, fill factor, efficiency – losses in solar cells – model of a solar cell, effect of series and shunt resistance on efficiency , effect of solar radiation on efficiency – solar cell design – design for high $I_{SC}$ – Design for high $V_{OC}$ – design for high FF – Analytical techniques.

**UNIT-III: SOLAR PHOTOVOLTAIC MODULES**

Solar PV Modules from solar cells – series and parallel connection of cells – mismatch in module – mismatch in series connection – hot spots in the module , bypass diode – mismatching in parallel diode – design and structure of PV modules – number of solar cells in a module, wattage of modules, fabrication of PV module – PV module power output.

**UNIT-V: BALANCE OF SOLAR PV SYSTEMS**

Basics of Electromechanical cell – factors affecting performance – batteries for PV systems – DC to DC converters – charge controllers – DC to AC converters(Inverters) – Maximum Power Point tracking (MPPT) – Algorithms for MPPT.

**UNIT V: PV SYSTEM DESIGN AND GRID CONNECTED APPLICATIONS**

Introduction to solar PV systems – standalone PV system configuration – design methodology of PV systems – design of PV powered DC fan without battery, standalone system with DC load using MPPT, design of PV powered DC pump, design of standalone system with battery and AC/DC load – wire sizing in PV system – precise sizing of PV systems –off- grid systems – layout – design – grid-Tied systems – mini-grid systems - Hybrid PV systems – grid connected PV systems.

**TEXT BOOKS:**

1. “Solar Photovoltaics Fundamentals, Technologies and Applications” by Chetan singh solanki, PHI publications-2011.

**REFERENCES:**

1. Solar Energy Fundamentals and applications by H.P. Garg, J. Prakash “Tata McGraw- Hill publishers I$^{st}$ edition”
2. S.Rao & B.B.Parulekar, “Energy Technology”, 4th edition, Khanna publishers, 2005.

## 15D21208 WIND ENERGY CONVERSION SYSTEMS

**UNIT-I: FUNDAMENTALS OF WIND TURBINES**

Historical background - basics of mechanical to electrical energy conversion in wind energy - types of wind energy conversion devices – definition - solidity, tip speed ratio, power coefficient, wind turbine ratings and specifications - aerodynamics of wind rotors - design of the wind turbine rotor

**UNIT-II: WIND TURBINE CONTROL SYSTEMS & SITE ANALYSIS**

Power speed characteristics - torque speed characteristics - Pitch angle control – stall control – power electronic control – Yaw control – Control strategy – wind speed measurements – wind speed statistics – site and turbine selection.

**UNIT-III: BASICS OF INDUCTION AND SYNCHRONOUS MACHINES**

The Induction Machine – constructional features - equivalent circuit model - performance characteristics - saturation characteristics – dynamic d-q model – the wound – field synchronous machine – the permanent magnet synchronous machine – power flow between two synchronous sources – induction generator versus synchronous generator – stand alone & grid integration techniques for synchronous machines – layout - .

**UNIT-IV: GRID CONNECTED AND SELF-EXCITED INDUCTION GENERATOR OPEARTION**

Constant – voltage, constant – frequency- single output system –double output system with current converter & voltage source inverter – equivalent circuits – reactive power and harmonics – reactive power compensation – variable – voltage, variable – frequency generation – the self- excitation process – circuit model for the self – excited induction generator – analysis of steady state operation – the steady state characteristics – the excitation requirement – effect of a wind generator on the network .

**UNIT-V: WIND GENERATION WITH VARIABLE-SPEED TURBINES AND APPLICATION**

Classification of schemes – operating area – induction generators – doubly fed induction generator – wound field synchronous generator – the permanent magnet generator – Merits and limitations of wind energy conversion systems – application in hybrid energy systems – diesel generator and photovoltaic systems – wind photovoltaic systems.

**TEXT BOOKS:**

1. S.N.Bhadra,D.Kastha, S.Banerjee, “ wind electrical systems” Oxford University Press-2005.

**REFERENCES:**

1. S.Rao & B.B.Parulekar, “Energy Technology”, 4th edition, Khanna publishers, 2005.
2. “Renewable Energy sources & Conversion Technology” by N.K.Bansal, Manfred Kleemann, Michael Meliss. Tata Mcgraw Hill Publishers.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY ANANTAPUR
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**Course Structure of R21 Academic Regulations for M.Tech (Regular) Programs with effect from AY 2021-2022**

# DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

## POWER AND INDUSTRIAL DRIVES

### I SEMESTER

| S.No. | Course Code | Subject Name | Cate Gory | Hours Per Week | | | Credits |
|---|---|---|---|---|---|---|---|
| | | | | L | T | P | |
| 1 | 21D23101 | Switched Mode Power Converters | PC | 3 | 0 | 0 | 3 |
| 2 | 21D23102 | Machine Modeling and Analysis | PC | 3 | 0 | 0 | 3 |
| 3 | **Professional Elective – I** | | | | | | |
| | 21D23103 | Power Electronic Control of DC Drives | PE | 3 | 0 | 0 | 3 |
| | 21D23104 | Modern Control Theory | | | | | |
| | 21D23105 | Energy Auditing and Management | | | | | |
| 4 | **Professional Elective – II** | | | | | | |
| | 21D23106 | Solar Energy Conversion Systems | PE | 3 | 0 | 0 | 3 |
| | 21D21107 | Smart Grid Technologies | | | | | |
| | 21D23107 | Wind Energy Conversion Systems | | | | | |
| 5 | 21D11109 | Research Methodology and IPR | MC | 2 | 0 | 0 | 2 |
| 6 | 21D11110 | English for Research Paper Writing | AC | 2 | 0 | 0 | 0 |
| | 21D11111 | Value Education | | | | | |
| | 21D11112 | Pedagogy Studies | | | | | |
| 7 | 21D23108 | Power Electronic Circuit Lab | PC | 0 | 0 | 4 | 2 |
| 8 | 21D23109 | Renewable Energy Sources Lab | PC | 0 | 0 | 4 | 2 |
| **Total** | | | | **16** | **00** | **08** | **18** |

## POWER AND INDUSTRIAL DRIVES

### II SEMESTER

| S.No. | Course Code | Subject Name | Cate Gory | Hours Per Week | | | Credits |
|---|---|---|---|---|---|---|---|
| | | | | L | T | P | |
| 1 | 21D23201 | Modern Power Electronics | PC | 3 | 0 | 0 | 3 |
| 2 | 21D21202 | FACTS Controllers | PC | 3 | 0 | 0 | 3 |
| 3 | **Professional Elective – III** | | | | | | |
| | 21D23202 | Advanced Electric Drives | PE | 3 | 0 | 0 | 3 |
| | 21D23203 | Advanced Power Semiconductor Devices & Protection | | | | | |
| | 21D23204 | Applications of Power Converters | | | | | |
| 4 | **Professional Elective – IV** | | | | | | |
| | 21D21205 | Power Quality | PE | 3 | 0 | 0 | 3 |
| | 21D23205 | AI Techniques in Electrical Engineering | | | | | |
| | 21D23206 | Digital Signal Processors and Applications | | | | | |
| 5 | 21D11209 | Technical Seminar | PR | 0 | 0 | 4 | 2 |
| 6 | 21D11210 | Disaster Management | AC | 2 | 0 | 0 | 0 |
| | 21D11211 | Constitution of India | | | | | |
| | 21D11212 | Stress Management by Yoga | | | | | |
| 7 | 21D23207 | Electric Drives Lab | PC | 0 | 0 | 4 | 2 |
| 8 | 21D21209 | FACTS Devices & Simulation Lab | PC | 0 | 0 | 4 | 2 |
| **Total** | | | | **14** | **00** | **12** | **18** |

# POWER AND INDUSTRIAL DRIVES

## III SEMESTER

| S.No. | Course Code | Subject Name | Cate Gory | Hours Per Week | | | Credits |
|---|---|---|---|---|---|---|---|
| | | | | L | T | P | |
| 1 | **Professional Elective – V** | | | | | | |
| | 21D23301 | Control & Integration of Renewable Energy Sources | PE | 3 | 0 | 0 | 3 |
| | 21D23302 | Energy Storage Technologies | | | | | |
| | 21D23303 | Hybrid Electric Vehicle Engineering | | | | | |
| 2 | **Open Elective** | | | | | | |
| | 21D20301 | Waste to Energy | OE | 3 | 0 | 0 | 3 |
| 3 | 21D23304 | Dissertation Phase – I | PR | 0 | 0 | 20 | 10 |
| 4 | 21D00301 | Co-Curricular Activities | PR | | | | 2 |
| **Total** | | | | **06** | **00** | **20** | **18** |

## IV SEMESTER

| S.No. | Course Code | Subject Name | Cate Gory | Hours Per Week | | | Credits |
|---|---|---|---|---|---|---|---|
| | | | | L | T | P | |
| 1 | 21D23401 | Dissertation Phase – II | PR | 0 | 0 | 32 | 16 |
| **Total** | | | | **00** | **00** | **32** | **16** |

**R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES**
**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING**
**(POWER AND INDUSTRIAL DRIVES)**

| Course Code | 21D23101 | SWITCHED MODE POWER CONVERTERS (21D23101) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | I | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

- Remember and understand the concept of advanced converter topologies.
- Apply the concept of topologies for various switching regulators.
- Analyse the working and waveforms of the converters designed.
- Evaluate the operation of converters in continuous and discontinuous modes.

**Course Outcomes (CO):** Student will be able to

- Remember and understand the concept of Buck and Boost switching regulator topologies push-pull &forward converter, voltage & current fed topologies.
- Apply the concept of topologies for various switching regulators.
- Analyse the concepts of half & full bridge converter topologies
- Evaluatetheoperationofcontinuousanddis-continuousFlybackconverter topologies

| UNIT - I | FUNDAMENTAL SWITCHING REGULATORS –BUCK AND BOOST TOPOLOGIES | LecHrs: 9 |
|---|---|---|

Buck Switching Regulator Topology: Basic Operation - Significant Current waveforms -Buck regulator efficiency-Design relations of output filter inductor and capacitor. Boost Switching Regulator Topology: Basic Operation – Quantitative relations –Discontinuous and Continuous modes –Design relations.

| UNIT - II | PUSH-PULL AND FORWARD CONVERTER TOPOLOGIES | LecHrs: 10 |
|---|---|---|

Push-Pull Topology: Basic Operation – Master/slave outputs - Flux imbalance -Power transformer design relations - Primary, secondary peak and RMS currents - output power and input voltage limitations – output filter design relations. Forward Converter Topology: Basic operation -Design relations - Slave output voltages -secondary load -freewheeling diode and inductor currents. Forward converter with unequal power and reset winding turns - power transformer design and output filter design.

| UNIT - III | HALF AND FULLBRIDGECONVERTERTOPOLOGIES | LecHrs: 10 |
|---|---|---|

Half Bridge Converter Topology: Basic operation-Half bridge magnetic-output filter calculations, blocking capacitor to avoid flux imbalance-Half bridge leakage inductance problems. Full Bridge Converter Topology: Basic operation-Full Bridge magnetic–output filter calculations – transformer primary blocking capacitor

| UNIT - IV | FLYBACKCONVERTERTOPOLOGIES | LecHrs: 10 |
|---|---|---|

Discontinuous-Mode Fly backs: Basic operation - relation between output voltage versus input voltage-on time output load - design relations and sequential decision requirements –fly back converter, disadvantages. Continuous Mode Fly backs: Basic operation - Discontinuous mode to continuous mode transition - design relations– continuous mode fly backs.

| UNIT - V | VOLTAGE-FEDANDCURRENT-FEDTOPOLOGIES | LecHrs: 9 |
|---|---|---|

Definitions-deficiencies of voltage fed pulse width modulated full wave bridge-buck voltage fed full wave bridge topology – basic operation buck voltage fed full wave bridge– advantages-drawbacks in buck voltage fed full wave bridge - buck current fed full wave bridge topology – basic operation – fly back current fed push pull topology.

**Textbooks:**

1. Pressman A.I, Switching Power Supply Design, McGraw Hill,3rd edition,2009.
2. Mitchell D.M, DC-DC Switching Regulator Analysis, McGrawHill, 1st edition, 1988

**Reference Books:**

1. Ned Mohan, Power Electronics, JohnWiley,3rd edition,2011.
2. Otmar Kingenstein, Switched Mode Power Supplies in Practice, John Wiley, 1st edition,1991.
3. BillingsK.H.,HandbookofSwitchedModePowerSupplies,McGrawHill,3rd edition, 2010.
4. Nave M.J, Power Line Filter Design for Switched-Mode Power Supplies, Mark Nave Consultants, 2nd edition, 2010.

**Online Learning Resources:**

| Course Code | 21D23102 | MACHINE MODELLING & ANALYSIS (21D23102) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | I | | 3 | 0 | 0 | 3 |

**Course Objectives:**To make the student

- Understand the basic principles for machine analysis and reference frame theory
- Apply the concept of Change of Variables, and Transformation to an Arbitrary Reference Frame
- Analyse the dynamic analysis of machines.
- Design the modelling of machines.

**Course Outcomes (CO):** Student will be able to

- Understand the Concept Magnetically Coupled Circuits, Types of DC machines, commonly used Reference Frames, machines variables, Time domain and state equations, Permanent Magnet Brushless DC Motor Operating principle.
- Apply the concept of Change of Variables and Transformation to an Arbitrary Reference Frame, Equal Area Criteria.
- Analyze the Free Acceleration Characteristics viewed from Various Reference Frames, Steady-State Analysis and its Operation ,dynamic analysis of machines, Mathematical modelling of PM Brushless DC motor.
- Design the modelling of DC machines, three phase Induction machines, Synchronous machine.

| UNIT - I | Basic Principles and Analysis of DC Machines | LecHrs: 10 |
|---|---|---|

Basic Principles for Machine Analysis:Magnetically coupled circuits - Machine windings - Air-Gap MMF-Windinginductances - Voltage equations.
Modelling and Analysis of DC Machines:Elementary theory of DC Machine - Voltage and Torque Equations- Types of DC Machines - Permanent and Shunt DC Motors - Time-Domain and State-Equations.

| UNIT – II | Reference Frame Theory | LecHrs: 9 |
|---|---|---|

Fundamentals of Transformations - Equations of Transformations - Change of Variables and Transformation to an Arbitrary Reference Frame - Commonly used Reference Frames - Transformation between Reference Frames - Steady-State Phasor Relationships and Voltage Equations.

| UNIT - III | Modelling& Dynamic Analysis of Three Phase Induction Machines | LecHrs: 10 |
|---|---|---|

Voltage and Torque Equations in Machine Variables - Voltage and Torque Equations in Arbitrary Reference Frame - Steady-State Analysis and its Operation.Free Acceleration Characteristics viewed from Various Reference Frames - Dynamic Performance during Sudden Changes in Load Torque - Dynamic Performance during A Three-Phase Fault at the Machine Terminals.

| UNIT - IV | Modelling& Dynamic Analysis of Synchronous Machines | LecHrs: 10 |
|---|---|---|

Voltage in Machine Variables - Torque equation in Machine Variables - Voltage Equations in Arbitrary and Rotor Reference Frame - Torque Equations in Substitute Variable- Steady-State Analysis and its Operation.Dynamic Performance of Synchronous Machine - Three-Phase Fault, Comparison of Actual and Approximate Transient Torque Characteristics, - Equal Area Criteria.

| **UNIT - V** | **Modelling of Special Machines** | **LecHrs: 9** |
|---|---|---|
| Modelling of Permanent Magnet Brushless DC Motor - Operating principle – Mathematical modelling of PM Brushless DC motor - PMDC Motor Drive Scheme. | | |

**Textbooks:**

1. PaulC. Krause, Oleg Wasyzczuk, ScottS, Sudhoff, "Analysis of Electric Machinery and Drive Systems", IEEE Press, 3rd Edition, 2013.
2. R. Krishnan,"Electric Motor Drives, Modelling, Analysis and Control" , Pearson Education India, 4th edition, 2015.

**Reference Books:**

1. P. C. Krause, "Analysis of Electric Machinery", McGraw Hill, 3rd edition, 2013
2. Samuel Seely, "Electro mechanical Energy Conversion", Tata McGraw Hill Publishing Company, 1st edition, 1962.
3. A.E, Fitzgerald, Charles Kingsley, Jr, and Stephan D ,Umanx, "ElectricMachinery" ,Tata McGraw Hill, 7thEdition, 2020.
4. P. Kundur, "Power System Stability and Control", MC Graw Hill Education, 1st edition, 2006.

**Online Learning Resources:**

**R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES**
**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING**
**(POWER AND INDUSTRIAL DRIVES)**

| Course Code | 21D23103 | POWERELECTRONIC CONTROLOFDCDRIVES (21D23103) (PE-I) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | I | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

- Understand the concept of separately excited single phase and three phase rectifier with DC Motor load drives.
- Apply various controlling techniques on DC motor Drives.
- Analyze the operations when various controlling techniques are applied on DC motor drives.
- Design of chopper controlled DC motor Drives working in different Quadrants

**Course Outcomes (CO):** Student will be able to

- Remember and understand the concept separately excited single phase and three phase rectifier with DC Motor load drives.
- Apply the concept of phase controlled technique for DC motor Drives.
- Analyse the current and speed controlled Drives.
- Design of chopper controlled DC motor Drives in various quadrants.

| UNIT - I | CONTROLLEDBRIDGERECTIFIER(1-Φ& 3-Φ)WITHDCMOTORLOAD | LecHrs: 10 |
|---|---|---|

SeparatelyexcitedDCmotorswithrectifiedsinglephasesupply-singlephasesemi-converterandsinglephasefullconverter forcontinuous anddiscontinuousmodes ofoperation–powerand power factor.Three-phasesemi-converterandthreephasefullconverterforcontinuousanddiscontinuousmodesofoperation–power and power factor– AdditionofFreewheeling diode.

| UNIT - II | THREEPHASENATURALLYCOMMUTATEDBRIDGECIRCUITASARECTIFIERORASANINVERTER | LecHrs: 9 |
|---|---|---|

Three phase controlled bridge rectifier with passive load impedance - resistive load and ideal supply – Highlyinductive load and ideal supply for load side and supply side quantities - shunt capacitor compensation – threephasecontrolled bridgerectifier inverter.

| UNIT - III | PHASE CONTROLLEDDCMOTORDRIVES | LecHrs: 9 |
|---|---|---|

Three phase controlled converter - control circuit - control modelling of three phase converter – Steady stateanalysis of three phase converter control DC motor drive – Two quadrant, Three phase converter controlledDCmotor drive – DC motor and load, converter.

| UNIT - IV | CURRENTANDSPEEDCONTROLLEDDCMOTORDRIVES | LecHrs: 10 |
|---|---|---|

Current and Speed controllers -current and speed feedback — Design of controllers - Current and Speedcontrollers – Motor equations– Filter in the speed feedback loop speed controller– currentreferencegenerator – current controller and flow chart for simulation – Harmonics and associated problems– sixthharmonicstorque.

| UNIT - V | CHOPPERCONTROLLEDDCMOTORDRIVES | LecHrs: 10 |
|---|---|---|

Principle of operation of the chopper– Four quadrant chopper circuit–Chopper for inversion – Chopperwith other power devices – model of the chopper –input to the chopper – Steady state analysis of choppercontrolledDC motor drives –ratingof thedevices– Pulsatingtorque – Closedloopoperation ofDCmotorDrivesSpeed controlled drive system – current control loop – pulse width modulated current controller – hysteresiscurrentcontroller– modelling of currentcontroller– design ofcurrent

**Textbooks:**

1. Fundamentalsof ElectricDrives –G.K.Dubey–NarosaPublications -2nd edition, 2020.
2. PowerSemiconductor drives–S.B.DewanandA.Straughen –Wiley India edition-1st edition, 2009.

**Reference Books:**

1. PowerElectronicsand motorcontrol–Shepherd,Hulley,Liang,CUPress, 2nd edition 1995
2. Electricmotordrives modelling,Analysisandcontrol –R.Krishnan, PHI, 5th edition, 2015
3. PowerElectronicCircuits,DevicesandApplications-M. H. Rashid, PHI, 4thedition, 2017

**Online Learning Resources:**

| Course Code | 21D23104 | MODERN CONTROL THEORY (21D23104) (PE-I) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | I | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

- Remember and understand the concept of state space representation, Solution of state equation, STM, linearization of nonlinear systems, controllability and observability concepts, principles of duality, concepts of optimal and Lyapunov stability.
- Apply the above concepts to analyze controllability, Observability and pole placement by state feedback.
- Analyze the concept of regulator, stability and sensitivity using various methods and disturbance rejection.
- Design Full order observer and reduced order observer.

**Course Outcomes (CO):** Student will be able to

- Understand the state space representation, controllability and observability concepts, principles of duality, concepts of optimal and Lyapunov stability.
- Apply the state equations, pole placement by state feedback.
- Analyze controllability &observability of state models.
- Design full order observer and reduced order observer.

| UNIT - I | STATE VARIABLE DISCRIPTION | LecHrs: 9 |
|---|---|---|

Introductory matrix algebra and linear Vector Space, State space representation of systems- Linearization of a non-linear System- Solution of state equations- Evaluation of State Transition Matrix (STM).

| UNIT - II | TRANSFORMATION, POLEPLACEMENT AND CONTROLLABILITY | LecHrs: 10 |
|---|---|---|

Similarity transformation and invariance of system properties due to similarity transformations. Minimal realization of SISO, SIMO and MISO transfer functions. Discretization of a continuous time state space model- Conversion of state space model to transfer function model using Fadeeva algorithm- Fundamental theorem of feedback control - Controllability and Controllable canonical form - Pole assignment by state feedback using Ackermann‘s formula– Eigen structure assignment problem.

| UNIT - III | OPTIMAL CONTROL | LecHrs: 10 |
|---|---|---|

Linear Quadratic Regulator (LQR) problem and solution of algebraic Riccati equation using Eigen value and Eigen vector methods- iterative method- Controller design using output feedback.

| UNIT - IV | OBSERVERS | LecHrs: 9 |
|---|---|---|

Observability and observable canonical form-Design of full order observer using Ackermann‘s formula -Bass Gura algorithm- Duality between controllability and observability- Full order Observer based controller design- Reduced order observer design.

| UNIT - V | STABILITY ANALYSIS AND SENSITIVITY | LecHrs: 10 |
|---|---|---|

Internal stability of a system- Stability in the sense of Lyapunov- Asymptotic stability of linear time invariant continuous and discrete time systems- Solution of Lyapunov type equation- Model decomposition and decoupling by state feedback- Disturbance rejection- sensitivity and complementary sensitivity functions.

**Textbooks:**

1. K. Ogata, "Modern Control Engineering", Prentice Hall, India, 5th edition, 2010.
2. T. Kailath, "Linear Systems", Perntice Hall, 2016.
3. N.K. Sinha, "Control Systems", New Age International, 4th edition, 2013.

**Reference Books:**

1. Panos J Antsaklis, and Anthony N.Michel,"LinearSystems", New-age international (P) LTD.Publishers, 2009.
2. John JDAzzoand C. H. Houpis, "LINEAR Control System Analysis And Design WithMatlae", Marcel Dekker, Inc., 5Th edition, 2003.
3. B.N.Dutta, "Numerical Methods for linear Control Systems", Elsevier Publication, 2007.
4. C.T. Chen "Linear System Theory and Design- Oxford Series 3rdEdition, ,1998.
5. Richard C. Dorf and Robert H. Bishop, "Modern Control Systems", 12th Edition, Pearson Edu., India, 2014

**Online Learning Resources:**

**R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES**
**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING**
**(POWER AND INDUSTRIAL DRIVES)**

| Course Code | 21D23105 | ENERGY AUDITING AND MANAGEMENT (21D23105) (PE-I) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | I | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

- Understand the current energy scenario and importance of energy conservation
- Acquire the knowledge about different energy efficient devices
- Measure thermal efficiency and other renewable resources.
- Design suitable energy monitoring system to analyze and optimize the energy consumption in an electrical system.

**Course Outcomes (CO):** Student will be able to

- Understand the importance of energy conservation, present energy scenario and various energy conservation devices available.
- Analyze different methodologies used to reduce losses and various techniques used for energy auditing.
- Analyze and apply various instruments available to study different parameters such as heating etc.
- Apply the economic evaluation of energy conservation measures.

| UNIT - I | Energy audit and demand side management (DSM) in power utilities | LecHrs: 10 |
|---|---|---|

Energy Scenario & Conservation -Demand Forecasting Techniques- Integrated Optimal Strategy for Reduction of T&D Losses - DSM Techniques and Methodologies- Loss Reduction in Primary and Secondary Distribution system and capacitors - Energy Management — Role of Energy Managers – Energy Audit-Metering

| UNIT - II | Energy audit | LecHrs: 10 |
|---|---|---|

Energy audit concepts - Basic elements and measurements - Mass and energy balances - Scope of energy auditing in industries - Evaluation of energy conserving opportunities and environmental management - Preparation and presentation of energy audit reports - case studies and potential energy savings.

| UNIT - III | Instrumentation | LecHrs: 10 |
|---|---|---|

General Audit Instrumentation –Measuring building losses – Applications of IR thermo graphy – Measurement of electrical system performance – Measurement of heating, ventilation, air conditioning system performance – Measurement of combustion systems.

| UNIT - IV | Energy conservation | LecHrs: 9 |
|---|---|---|

Energy conservation in HVAC systems and thermal power plants, Solar systems, Fan and Lighting Systems - Different light sources and luminous efficiency

| UNIT - V | Economic evaluation of energy conservation | LecHrs: 9 |
|---|---|---|

Energy conservation in electrical devices and systems - Economic evaluation of energy conservation measures - Electric motors and transformers - Inverters and UPS - Voltage stabilizers.

**Textbooks:**

1. Frank kreith and D. Yogi goswamy/ Editors, “Energy Management and conservation handbook”. NewYork,2008.
2. WC Turner: Energy Management Handbook, Seventh Edition, (Fairmont Press Inc., 2007)

3. YP Abbi and Shashank Jain: Handbook on Energy Audit and Environment Management, (TERIPress, 2006)

**Reference Books:**

1. Albert Thumann, and William J. Younger, "Handbook of Energy Audits", Marcel Dekker, Inc., Newyork, 6th edition, 2003.
2. D.A.Reay, IndustrialEnergyConservation-Pergamon Press, 1980.T.L.Boten,
3. LiptakB.G.,(Ed)InstrumentEngineersHandbook,ChintonBookCompany, 2004.
4. HodgeB.K,AnalysisandDesign ofEnergySystems,Prentice Hall, 2002.
5. Larry C.Witte, Schmidt & Brown, Industrial energy management and utilization. Hemisphere publishing, Co.NewYork,1988.

**Online Learning Resources:**

| Course Code | 21D23106 | SOLAR ENERGY CONVERSION SYSTEMS (21D23106) (PE–II) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | I | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

- Understand the fundamentals of solar cell
- Apply the photovoltaic systems and various technologies of solar PV cells, about manufacture,sizing and operating techniques
- Analyze Series and parallel connection of cells, Hot spots in the module,Algorithms for MPPT.
- Design Solar cells and PV system.

**Course Outcomes (CO):** Student will be able to

- Understand thefundamentals of solar cell,Solar PV Modules from solar cells, system types, Standalone PV system configuration, Maximum Power Point tracking (MPPT).
- Apply the concept of various technologies of solar PV cells, manufacture, sizing and operating techniques.
- Analyze the concept of Effect of series and shunt resistance on efficiency, Effect of solar radiation on efficiency, Analytical techniques, Hot spots in the module,Algorithms for MPPT.
- Design of PV powered DC fan without battery, Standalone system with DC load using MPPT, PV powered DC pump, standalone system with battery and AC/DC load.

**UNIT - I SOLAR CELL FUNDAMENTALS — LecHrs: 9**

Introduction to PV- World energy scenario – Need for sustainable energy sources – Current status of Renewable energy sources – Place of photovoltaic in Energy supply – Solar radiation – The sun and earth movement – Angle of sunrays on solar collectors – Sun tracking – Estimating solar radiation empirically–Measurement of solar radiation.

**UNIT - II DESIGN OF SOLAR CELLS — LecHrs: 10**

Introduction to Solar cells- Solar cell design-Design for high $I_{SC}$ – Design for high $V_{OC}$ – Designfor high FF-Upper limits of cell parameters – Short circuit current, open circuit voltage, fill factor, efficiency, losses in solar cells – Model of a solar cell- Effect of series and shunt resistance on efficiency- Effect of solar radiation on efficiency- Analytical techniques.

**UNIT - III SOLAR PHOTO VOLTAIC MODULES — LecHrs: 10**

Solar PV Modules from solar cells– Series and parallel connection of cells– Mismatch in module – Mismatch in series connection – Hot spots in the module- Bypass diode – Mismatching in parallel diode – Design and structure of PV modules – Number of solar cells in a module-Wattage of modules- Fabrication of PV module–PV module power output.

**UNIT - IV BALANCEOF SOLAR PV SYSTEMS — LecHrs: 9**

Basics of Electromechanical cell –Factors affecting performance – Batteries for PV systems –DC to DC converters – Charge controllers – DC to AC converters(Inverters) – Maximum Power Point tracking(MPPT)–Algorithms for MPPT.

| **UNIT - V** | **PV SYSTEM DESIGN AND APPLICATIONS** | **LecHrs: 10** |
|---|---|---|

Introduction to solar PV systems – Standalone PV system configuration – Design methodology of PV systems – Design of PV powered DC fan without battery- Standalone system with DC load using MPPT- Design of PV powered DC pump- Design of standalone system with battery and AC/DC load – Wire sizing in PV system – Precise sizing of PV systems – Hybrid PV systems – Grid connected PV systems.

**Textbooks:**

1. Chetansinghsolanki “Solar Photovoltaic Fundamentals: Technologies and Applications”, PHI publications, 3rd edition, 2015.

**Reference Books:**

1. H.P.Garg, J.Prakash “Solar Energy Fundamentals and applications “Tata McGraw-Hill publishers 1st edition”, 2000.
2. S.Rao& B.B.Parulekar,“EnergyTechnology”, Khanna publishers, 4th edition, 2005.

**Online Learning Resources:**

| Course Code | 21D21107 | SMART GRID TECHNOLOGIES (21D21107) (PE-II) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | I | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

- To understand the basic concepts, components and architecture of smart grid
- To describe the various measurement technologies in smart grid
- To summarize the importance of renewable energy in smart grid
- To analyze the tools to improve performance and stability in smart grid

**Course Outcomes (CO):** Student will be able to

- Understand the basic concepts, components and architecture of smart grid
- Apply the various measurement technologies in smart grid
- Evaluate the importance of renewable energy in smart grid
- Analyze the tools to improve performance and stability in smart grid

**UNIT - I SMART GRIDS — LecHrs: 9**

Smart grid introduction, ageing assets and lack of circuit capacity, thermal constraints, operational constraints, security of supply, national initiatives, early smart grid initiatives, active distribution networks, virtual power plant, other initiatives and demonstrations, overview of the technologies required for the smart grid.

**UNIT - II TRANSMISSION AND DISTRIBUTION MANAGEMENT — LecHrs: 10**

Data Sources, Energy Management System, Wide Area Applications, Visualization Techniques, Data Sources and Associated External Systems, SCADA, Customer Information System, Modelling and Analysis Tools, Distribution System Modeling, Topology Analysis, Load Forecasting, Power Flow Analysis, Fault Calculations, State Estimation, Applications, System Monitoring, Operation, Management, Outage Management System, Overview of energy storage technologies.

**UNIT - III SMART METERING AND DEMAND SIDE INTEGRATION — LecHrs: 10**

Introduction, smart metering – evolution of electricity metering, key components of smart metering, smart meters: an overview of the hardware used – signal acquisition, signal conditioning, analogue to digital conversion, computation, input/output and communication. Communication infrastructure and protocols for smart metering - Home area network, Neighbourhood Area Network, Data Concentrator, meter data management system, Protocols for communication. Demand Side Integration- Services Provided by DSI, Implementation of DSI, Hardware Support, Flexibility Delivered by consumers from the Demand Side, System Support from DSI.

**UNIT - IV COMMUNICATION TECHNOLOGIES FOR THE SMART GRID — LecHrs: 9**

Data Communications: Dedicated and Shared Communication Channels, Switching Techniques, Circuit Switching, Message Switching, Packet Switching, Communication Channels, Introduction to TCP/IP.

Communication Technologies: IEEE 802 Series, Mobile Communications, Multi-Protocol Label Switching, Power line Communication.

| **UNIT - V** | **INFORMATION SECURITY FOR THE SMART GRID** | **LecHrs: 10** |
|---|---|---|
| Introduction, Encryption and Decryption, Symmetric Key Encryption, Public Key Encryption, Authentication, Authentication Based on Shared Secret Key, Authentication Based on Key Distribution Center, Digital Signatures, Secret Key Signature, Public Key Signature, Message Digest. | | |

**Textbooks:**

1. JanakaEkanayake, KithsiriLiyanage, et.al.,Smart Grid Technology and Applications, Wiley Publications, 1st edition, 2012.
2. Bharat Modi, Anuprakash, Yogesh Kumar, Fundamentals of Smart Grid Technology, S.K Kataria& Sons, 1stedition, 2019.

**Reference Books:**

1. Eric D. Knapp, Raj Samani, Applied Cyber Security and the Smart Grid-Implementing Security Controls into the Modern Power Infrastructure, Syngress Publishers, 1st edition, 2013.
2. NouredineHadjsaid, Jean Claude Sabonnadiere, Smart Grids, Wiley Blackwell Publications, 1st edition, 2012.
3. Peter-Fox Penner, Smart Power: Climate Changes, the Smart Grid and the future of electric utilities, Island Press, 1st edition, 2010.
4. James Momoh, Smart Grid: Fundamentals of Design and Analysis, Wiley, IEEE Press, 1st edition, 2012

**Online Learning Resources:**

| Course Code | 21D23107 | WIND ENERGY CONVERSION SYSTEMS (21D23107) (PE-II) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | I | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

- To understand the application of wind energy and wind energy conversion system.
- To Design wind turbine blades and know about applications of wind energy for water pumping and electricity generation.
- To apply the concepts of fixed speed and variable speed,wind energy conversion systems.
- To analyze the grid integration issues.

**Course Outcomes (CO):** Student will be able to

- Understand the concepts of fixed speed and variable speed wind energy conversion systems.
- Analyze the grid integration issues.
- Apply variable speed turbines for wind generation.
- Design and control principles of wind turbine.

**UNIT - I | FUNDAMENTALS OF WIND TURBINES | LecHrs: 10**

Historical background - Basics of mechanical to electrical energy conversion in wind energy -Types of wind energy conversion devices – Definition - Solidity, tip speed ratio, power coefficient, wind turbine ratings and specifications- Aerodynamics of wind rotors - Design of the wind turbine rotor.

**UNIT - II | WIND TURBINE CONTROL SYSTEMS & SITE ANALYSIS | LecHrs: 9**

Wind Turbine-Torque speed characteristics-Pitch angle control –Stall control –Power electronic control – Yaw control – Control strategy – Wind speed measurements – Wind speed statistics –Site and turbine selection.

**UNIT - III | BASICS OF INDUCTION AND SYNCHRONOUS MACHINES | LecHrs: 10**

The Induction Machine – Constructional features-Equivalent circuit model- Performance characteristics -Saturation characteristics – Dynamic d-q model – The wound field synchronous machine – The permanent magnet synchronous machine – Power flow between two synchronous sources – Induction generator versus synchronous generator.

**UNIT - IV | GRID CONNECTED AND SELF-EXCITED INDUCTION GENERATOR OPEARTION | LecHrs: 10**

Constant voltage, constant frequency- Single output system –Double output system with current converter & voltage source inverter–Equivalent circuits–Reactive power and harmonics- Reactive power compensation–variable voltage, variable frequency–The self-excitation process–Circuit model for the self-excited induction generator–Analysis of steady state operation–The excitation requirement–Effect of a wind generator on the network.

**UNIT - V | WIND GENERATION WITH VARIABLE- SPEED TURBINES AND APPLICATION | LecHrs: 9**

Classification of schemes–Operating area–Induction generators–Doubly fed induction generator – Wound field synchronous generator – The permanent magnet generator – Merits and limitations of wind energy conversion systems – Application in hybrid energy systems – Diesel generator and photo voltaic systems –Wind photovoltaic systems.

| **Textbooks:** |
|---|
| 1. S.N. Bhadra, D. Kastha, S. Banerjee, “wind electrical systems”, Oxford University Press, 1st edition, 2005.<br>2. 2. Banshi D. Shukla, “Engineering of Wind Energy”, Jain Brothers, 1st edition, 2018 |
| **Reference Books:** |
| 1. S.Rao& B.B. Parulekar, “EnergyTechnology”, Khanna publishers, 4th edition, 2005.<br>2. N.K.Bansal,M. Kleemann,MichaelMeliss, RenewableEnergysources&ConversionTechnology,TataMcgraw HillPublishers & Co., 1st edition, 1990. |
| **Online Learning Resources:** |
| |

| Course Code | 21D23108 | POWERELECTRONICS CIRCUITS LAB (21D23108) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | I | | 0 | 0 | 4 | 2 |

**Course Objectives:**To make the student

- UnderstandtheoperationofPowerElectronicconverters
- GainafairknowledgeontheprogrammingandsimulationofPowerElectronicconverters.
- Apply the MATLAB/ Simulink for various controllers
- Design a rectifier, inverter, chopper, cycloconverter and AC voltage controller

**Course Outcomes (CO):** The student will be able to

- Understandthebasic concept and its operation ofPowerElectronicconverters
- Analyse the output waveforms of the various converters designed
- Apply mathematical relations to find THD and verify it practically
- Design different controllersusingSimulink

**List of Experiments**:

1. Single PhaseFullyControlledConverterwithRandR-L loadsusingMATLAB
2. ThreePhaseFullyControlledConverterwithRandR-L loadsusingMATLAB
3. Single PhaseACVoltageControllerwithRandR-LloadsusingMATLAB.
4. ThreePhaseACVoltageControllerwithRandR-LloadsusingMATLAB.
5. ThreePhaseInverterin180°& 120° Conduction Mode with Star & Delta Connected loads using MATLAB.
6. Buck, Boost and Buck- Boost converter using MATLAB.
7. Single Phase cycloconverter using MATLAB
8. Three Phase cycloconverter using MATLAB.
9. Single Phase Full Controlled Converter with R and R-L loads.
10. Designing of induction motor using Simulink

**References:**

1. PowerElectronicCircuits,DevicesandApplications-M.H.Rashid–PHI,2017
2. NedMohan,PowerElectronics, JohnWiley,3rdedition,2011

| Course Code | 21D23109 | RENEWABLE ENERGY SOURCES LAB (21D23109) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | I | | 0 | 0 | 4 | 2 |

**Course Objectives:** To make the student

- To impart knowledge on I-V and P-V curves and Series and Parallel connection of Solar systems
- To study the sun tracking and MPPT Charge Controllers of Solar systems
- To observe the Power, Voltage & Frequency Measurement of Wind Generator
- To learn the Effect of temperature variation and Irradiation on Photovoltaic Array

**Course Outcomes (CO):** Student will be able to

- Obtain the I-V and P-V curves and Series and Parallel connection of Solar systems
- Understand the sun tracking and MPPT Charge Controllers of Solar systems
- Determine Power, Voltage & Frequency of Wind Generator
- Analyse the Effect of temperature variation and Irradiation on Photovoltaic Array

**List of Experiments**:

1. Draw the I-V and P-V curves of Solar Panel using P-V Panel
2. Study of Series and Parallel connection of Solar Panels
3. Study of Sun tracking system
4. Maximum Power Point Tracking Charge Controllers
5. Inverter control for Solar PV based systems
6. Power, Voltage & Frequency Measurement of output of Wind Generator
7. Impact of load and wind speed on power output and its quality
8. Performance of frequency drop characteristics of induction generator at different loading condition
9. Charging and Discharging characteristics of Battery

**Simulation Experiments**

1. Modelling of PV Cell
2. Effect of temperature variation on Photovoltaic Array
3. Effect of Irradiation on a Photovoltaic Array
4. Design of solar PV boost converter using P&O MPPT technique

**Note: Conduct any 7 experiments from 1-9 list and minimum 3 experiments from 1-4 of Simulation experiments**

References:

| **Course Code** | **21D23201** | **MODERNPOWERELECTRONICS (21D23201)** | **L** | **T** | **P** | **C** |
|---|---|---|---|---|---|---|
| **Semester** | **II** | | **3** | **0** | **0** | **3** |

**Course Objectives:**To make the student

- Remember and understand the construction, operation and characteristics of various power semiconductor devices and to analyze the cause of voltage unbalance and necessary actions for equalization of GCTs and IGBTs.
- Analyze the construction and working principle of various types of resonant pulse inverters, resonant converters and multi inverters.
- Analyze the various pulse modulations and advanced modulations techniques available.
- Apply the above concepts to choose appropriate device for a particular converter topology.

**Course Outcomes (CO):** Student will be able to

- Understand the characteristics of various power semiconductor devices.
- Analyze the operation of various types of resonant pulse inverters, resonant converters and multi inverters.
- Analyze various pulse modulation and advanced modulation techniques available.
- Apply the above concepts to choose appropriate device for particular topology.

| **UNIT - I** | **HIGH-POWERSEMICONDUCTORDEVICES** | **LecHrs: 9** |
|---|---|---|

Introduction – High Power Switching Devices – Diodes – Silicon-Controlled Rectifier (SCR) – Gate TurnOff (GTO) Thyristor –Gate Commutated Thyristor (GCT) –Insulated Gate Bipolar Transistor (IGBT) –Other Switching Devices –Operation of Series Connected Devices –Main Causes of Voltage Unbalance –VoltageEqualization forGCTs– VoltageEqualization forIGBTs.

| **UNIT - II** | **RESONANTPULSEINVERTERS** | **LecHrs: 10** |
|---|---|---|

Resonantpulseinverters–Seriesresonantinverters-Seriesresonantinverterswithunidirectionalandbidirectionalswitches-Analysisofhalfbridgeresonantinverter-EvaluationofcurrentsandVoltagesofasimpleresonantinverter–Analysisofhalfbridgeandfullbridgeresonantinverterwithbidirectionalswitches–Frequencyresponseofseriesresonantinverter forseriesloadedinverterand parallel resonant inverters–Voltagecontrolofresonantinverters- Class-Eresonant inverter–Class-Eresonant rectifier- Evaluation of values of C and L for class E inverter and Class E rectifier – Numerical problems.

| **UNIT - III** | **RESONANT CONVERTERS** | **LecHrs: 10** |
|---|---|---|

Resonant converters- Zero current switching resonant converters – L type - M type– Zero voltage Switching resonant converters – comparison between ZCS and ZVSresonant converters- Two quadrant ZVS resonant converters – Resonant dc link inverters- Evaluation of LandC forzero current switchinginverter – Numerical problems.

| **UNIT - IV** | **MULTILEVELINVERTERSI** | **LecHrs: 10** |
|---|---|---|

Sinusoidal PWM –Modulation Scheme –Harmonic Content –Over modulation–Third HarmonicInjectionPWM–SpaceVectorModulation–SwitchingStates–SpaceVectors–DwellTimeCalculation–Modulation Index – Switching Sequence– Spectrum Analysis –Even-Order Harmonic Elimination –Discontinuous Space Vector Modulation– H-Bridge Inverter– Bipolar Pulse Width Modulation – Unipolar Pulse Width Modulation.

| **UNIT - V** | **MULTILEVELINVERTERSII** | **LecHrs: 10** |
|---|---|---|

Multilevel Inverter Topologies–CHBInverterwithEqualDCVoltage–H-BridgeswithUnequalDC Voltages - Carrier Based PWM Schemes – Phase-Shifted Multicarrier Modulation–Level-Shifted MulticarrierModulation– Comparison Between Phase and Level Shifted PWM Schemes –Staircase Modulation –Diode Clamped Multilevel Inverters – Three Level Inverter – Converter Configuration –Switching State –Commutation–SpaceVectorModulation–StationarySpaceVectors–DwellTimeCalculation–Relationship Between $V_{ref}$ Location andDwell Times – Switching Sequence Design – Inverter OutputWaveformsand Harmonic Content– Even-Order Harmonic Elimination.

**Textbooks:**

1. MohammedH.Rashid, "PowerElectronics",PearsonEducation, 4th edition, 2017.
2. NedMohan,ToreM.UndelandandWilliamP.Robbind, PowerElectronics",Johnwiley&Sons, 3rd edition, 2007.

**Reference Books:**

1. DanielW. Hart, "PowerElectronics",McGrawHillPublications,1st edition, 2010.
2. V.R.Moorthi, "PowerElectronicsDevices,CircuitsandIndustrialapplications",OxfordUniversityPress,2005.
3. Dr.P.S.Bimbhra, "PowerElectronics",KhannaPubishers,2006.
3. PhilipT.Krein, "ElementsofPower Electronics",OxfordUniversityPress,2nd edition, 2014.
4. BinWu, "High-PowerConvertersandACDrives",IEEEPressAJohnWiley&Sons, 2ndedition, 2017.

**Online Learning Resources:**

| Course Code | 21D21202 | FACTS CONTROLLERS (21D21202) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | II | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

- To understand the fundamentals of FACTS Controllers, Importance of controllable parameters and types of FACTS controllers & their benefits.
- To explain control of STATCOM and SVC and their comparison and the regulation of STATCOM.
- To remember the objectives of Shunt and Series compensation.
- To analyze the functioning and control of GCSC, TSSC and TCSC.

**Course Outcomes (CO):** Student will be able to

**CO 1:** Understand various control techniques for the purpose of identifying the scope and for selection of specific FACTS controllers.
**CO 2:** Remember different types of controllable VAR generation and variable impedance techniques.
**CO 3:** Design simple converters using FACTS controllers.
**CO 4:** Understand the operation of Unified Power Controller and Hybrid Arrangements.

**UNIT - I** | **FACTS CONCEPTS, VSIANDCSI** | Lecture Hrs: 10

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. Single phase three phase full wave bridge converters transformer connections for 12pulse 24 and 48 pulse operation. Three level voltage source converter, pulse width modulation converter, basic concept of current source Converters, and comparison of current source converters with voltage source converters.

**UNIT - II** | **SHUNTCOMPENSATION** | Lecture Hrs: 8

Objectives of shunt compensation - Methods of controllable var generation - Variable impedance type static var generators - switching converter type var generators - hybrid var generators – Comparison of SVC and STATCOM.

**UNIT - III** | **SERIESCOMPENSATION** | Lecture Hrs: 12

Objectives of series compensation–GTO Thyristor Controlled Series Capacitor (GCSC)-Thyristor Switched Series Capacitor (TSSC) - Thyristor Controlled Series Capacitor (TCSC) - Control schemes for TCSC, TSSC and TCSC.

**UNIT - IV** | **UNIFIEDPOWER FLOW CONTROLLER (UPFC)** | Lecture Hrs:12

Introduction - The Unified Power Flow Controller - Basic Operating Principles - Conventional Transmission Control Capabilities - Independent Real and Reactive Power Flow Control - Control Structure – Basic Control System for P and Q Control-Hybrid Arrangements: UPFC With a Phase Shifting Transformer.

**UNIT - V** | **INTERLINE POWER FLOW CONTROLLER (IPFC)** | Lecture Hrs:10

Introduction, basic operating principle and characteristics of IPFC, control structure, practical and application considerations, generalized and multifunctional FACTS controllers

| **Textbooks:** |
| --- |
| 1. Understanding FACTS–Concepts and technology of Flexible AC Transmission systems, Narain G. Hingorani, Laszlo Gyugyi, IEEEPress, WILEY,1st Edition,2000, Reprint2015.<br>2. FACTS Controllers in Power Transmission and Distribution, Padiyar K.R., New Age International Publishers, 1st Edition, 2007. |
| **Reference Books:** |
| 1. Flexible AC Transmission Systems: Modelling and Control, Xiao–Ping Zhang, Christian Rehtanz, Bikash Pal, Springer, 2012, First Indian Reprint,2015.<br>2. FACTS–Modelling and Simulationin Power Networks, EnrigueAcha, Claudio R. Fuerte –Esquival, Huge Ambriz –perez, Cesar Angeles –Camacho, WILEY, 1st edition, 2004. |
| **Online Learning Resources:** |

| Course Code | 21D23202 | ADVANCEDELECTRICDRIVES (21D23202) (PE-III) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | II | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

- Remember and understand the working principle and control of various AC and Special purpose motor Drives.
- Analyze the controlstrategiesforVSIfedsensor-lessinductionmotordrives,CSIfedinductionmotordrives, and VSIfedpoly– phaseinduction motors.
- Analyze and apply controlschemesforPMSM,BLDCandSwitchedReluctanceMotordrives.
- Design highperformanceinductionmotordrivesusingtheprinciplesofScalarcontrolanddevelop vector control, direct torque control and introduction of five phase induction motor drive.

**Course Outcomes (CO):** Student will be able to

- Understand the working principle and operation of AC and Special purpose motor Drives.
- Formulate the controlstrategiesforVSIfedsensor-lessinductionmotordrives,CSIfedinductionmotordrives, and VSIfedpoly– phaseinduction motors.
- Implement controlschemesforPMSM,BLDCandSwitchedReluctanceMotordrives.
- AnalyzehighperformanceinductionmotordrivesusingtheprinciplesofScalarcontroland develop vector control, direct torque control and introduction of five phase induction motor drive.

| UNIT - I | Induction Motor drives | LecHrs: 10 |
|---|---|---|

Control of Induction Motor Drive - Scalar control of induction motor-Principle of vector control and field orientation Sensor less control and flux observers - Direct torque and fluxcontrol of induction motor Multilevel converter-fed induction motor drive - Utility friendly induction motordrive Implementation of V/f control with slip compensation scheme, Review of dq0 model of 3 – □ IM withsimulation studies.

| UNIT - II | Control techniques of IM drives | LecHrs: 10 |
|---|---|---|

Direct vector control -Indirect vector control with feedback-Indirectvectorcontrolwithfeed–forward-Indirectvectorcontrolinvariousframesofreference -Decoupling of vector control with feed forward compensation - sensor less control of IM, Direct TorqueControl of IM - Speed control of wound induction motor with rotor side control - introduction to five phaseinduction motordrives.

| UNIT - III | Synchronous Motor Drives | LecHrs: 9 |
|---|---|---|

Control of Synchronous Motor - Self-controlled synchronous motor –Vectorcontrolofsynchronousmotor –Cycloconverterfedsynchronousmotordrive –Controlofsynchronousreluctancemotor.

| UNIT - IV | Permanent Magnet Drives | LecHrs: 9 |
|---|---|---|

PM Synchronous motors: Types – Construction - operating principle-Expression for torque - Model of PMSM - Implementation of vector control for PMSM - BLDC drives- PMDCmotordrives.

| UNIT - V | SRM DRIVE & ITS CONTROLLER | LecHrs: 10 |
|---|---|---|

Construction - Operating Principle -Torque expression-SRM configuration and its controller design – converter topologies – control strategies – Sensor less control.Principlesoffuzzylogiccontrolandneuralnetwork–Designmethodologyandblockdiagramimplementation of DC drive and vector controlled induction motor.Recent trends in fuzzy control ofelectrical drives.MATLAB simulation – Fuzzy logic speed control of three phase induction motor drive –Adaptivespeed control forinduction motor drives usingneural network.

**Textbooks:**

1. ModernPowerElectronics&ACDrives – B.K.Bose,Pearson, Second edition,2005.
2. R.Krishnan, "ElectricMotorDrives:Modelling,AnalysisandControl", Pearson, 1st edition,2015.

**Reference Books:**

1. Bin-Wu, "High– PowerConvertersand ACDrives",IEEEPress, John Wiley&Sons, 2nd edition, 2017
2. M.B.Patil,V.Ramanarayanan,V.T.Ranganathan, "SimulationofPowerElectronicCircuits",NarosaPublications,2009, Reprint 2013.
3. RelevantPapersfromjournals.
4. P.C. Krause,O. Wasynczuk,S. D. Sudhoff and Steven D. Pekarek, "Analysis ofElectric Machinery", Wiley, IEEE Press, 3rd edition, 2013.
5. P. S. Bhimbra, "Generalized Theoryof ElectricMachines", KhannaPublication, 7th edition, 2021.
6. Ion Boldea , Syed A. Nasar "Electric Drives 3rd Edition, Kindle Edition" 3rd Edition,2016.

**Online Learning Resources:**

| **Course Code** | **21D23203** | **ADVANCED POWER SEMICONDUCTOR DEVICES AND PROTECTION (21D23203) (PE-III)** | **L** | **T** | **P** | **C** |
|---|---|---|---|---|---|---|
| **Semester** | **II** | | **3** | **0** | **0** | **3** |

**Course Objectives:** To make the student

- Remember and understand the construction, operation, characteristics and safe operating regions of various power semiconductor devices such as BJT, MOSFET, GTO and IGBT.
- Apply the basics of above to understand the various types of emerging power semiconductor devices such as power JFET and MOS controlled thyristor.
- Analyze the concept of Electro Magnetic Interference, Noise, their sources and effect of them on electronic equipment.
- Design protection devices and circuits like heat sinks, voltage and current protection circuits.

**Course Outcomes (CO):** Student will be able

- To understand the characteristics of various power semiconductor devices such as BJT, MOSFET, GTO and IGBT
- Apply the above to understand the various types of emerging power semiconductor devices
- To analyze the concept of Electro Magnetic Interference, Noise, their sources and effect of them on electronic equipment.
- To design protection devices and circuits like heat sinks, voltage and current protection circuits.

| **UNIT - I** | **BJTS &Power MOSFET** | **LecHrs: 10** |
|---|---|---|

Introduction- Vertical power transistor structures- I-V characteristics- Operation – Switchingcharacteristics-Break down voltages-Second break down- ON state losses- Safe Operation Areas- Design of drivecircuitsfor BJTs- Snubbercircuits for BJTs and Darlingtons.

PowerMOSFETs -Introduction-Basicstructures- I-Vcharacteristics- Physicsofdeviceoperation-SwitchingCharacteristics-Operationlimitations – SafeOperatingAreas- Design of gate drivecircuits-Snubbercircuits.

| **UNIT - II** | **GTO & IGBT:** | **LecHrs: 10** |
|---|---|---|

Introduction- Basic structures- I-V characteristics- Physics of device operation-GTO switchingCharacteristics- Snubber circuits- Over protection ofGTOs.

InsulatedGateBipolarTransistors - Introduction- Basicstructures- I-Vcharacteristics-Physicsofdeviceoperation- LatchinIGBTswitching Characteristics-Devicelimits and SafeOperatingAreas- Snubber circuits.

| **UNIT - III** | **EMERGINGDEVICESANDCIRCUITS** | **LecHrs: 9** |
|---|---|---|

Introduction-Power junction field effect transistors- Field Controlled Thyristor- JFET based devices Versusotherpowerdevices- MOScontrolledThyristors- Highvoltageintegratedcircuits-NewSemiconductormaterials- Introduction to Gallium Nitride and Silicon Carbide Devices.

| UNIT - IV | PASSIVECOMPONENTSANDELECTROMAGNETICCOMPATIBILITY | LecHrs: 9 |
|---|---|---|
| Introduction- Design of inductor- Transformer design- Selection of capacitors and resistors- Current Measurements-Heatsinkingcircuitlayout–ElectromagneticInterference(EMI)-SourcesofEMIElectromagneticInterferencein Power ElectronicEquipment | | |
| **UNIT - V** | **NOISE & PROTECTION DEVICES** | **LecHrs: 10** |
| Noise sources in SMPS- Diode Storage Charge Noise- Noise generated due to switching-Common noisessources in SMPS- Noises Due to High frequency transformer- Measurement of Noise-MinimizingEMI-EMIshielding- EMIstandards.<br>ProtectionofDevices& Circuits - Cooling & Heat sinks – Thermal modeling of power switching devices-Snubber circuits – Reverse recoverytransients–Supplyand load sidetransients – Voltageprotections– Current protections. | | |

**Textbooks:**

1. M.H.Rashid, "PowerElectronicsCircuits,DevicesandApplications"Pearson Education, 4th edition, 2017.
2. MohanandUndeland, "PowerElectronicsConverters,ApplicationsandDesign", JohnWiley&Sons, 3rd edition, 2007.
3. B.W.Williams,"PowerElectronicsCircuitDevices,Driversand Applications and passive components",MC Graw hill higher education, 2nd edition, 1992.

**Reference Books:**

1. Vithayathil, "PowerElectronicsCircuits", MC Graw Hill Education, Indian edition, 2017.
2. W.C.Lander, "PowerElectronicsCircuits",TataMCGraw Hill,3rdEdition, 1995.
3. LoganathanUmanand, "PowerElectronics:EssentialsandApplications", WileyIndiaPvt. Ltd,2009.

**Online Learning Resources:**

1. http://nptelonlinecourses.iitm.ac.in/courses/108104011/

| Course Code | 21D23204 | APPLICATIONSOFPOWERCONVERTERS (21D23204) (PE-III) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | II | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

- Understand the power electronic application requirements.
- Remember the various power converters used in different applications for high and low voltage power supplies.
- Analyze the various power supplies used in modern microprocessor and computer loads.
- Apply the above concepts to design bi-directional DC-DC converters for charge/discharge applications.

**Course Outcomes (CO):** Student will be able

- To understand the power electronic application requirements.
- To identify the suitable power converter from the available configurations.
- To develop the improved power converters for any stringent application requirements.
- To design a bi-directional DC-DC converters for charge/discharge applications.

| UNIT - I | Inverters for Induction Heating | LecHrs: 9 |
|---|---|---|

For induction cooking – high frequency inverters for induction heating - Induction hardening – Melting – Electric welding control – Welding applications.

| UNIT - II | Power Converters for Lighting, pumping and refrigeration Systems | LecHrs: 10 |
|---|---|---|

Electronic ballast - LEDpower drivers for indoor and outdoor applications - PFC based grid fed LED drivers - PV / batteryfedLEDdrivers –PVfedpowersuppliesfor pumping/refrigeration - Applications.

| UNIT - III | HighVoltagePowerSupplies | LecHrs: 10 |
|---|---|---|

Power supplies for X-ray applications - Power supplies forradar applications-Powersuppliesforspace applications.

| UNIT - IV | Low voltage high current power supplies | LecHrs: 9 |
|---|---|---|

Power converters for modern microprocessor andcomputerload

| UNIT - V | Bi-directionalDC-DC(BDC)converters | LecHrs: 10 |
|---|---|---|

Electrictraction - Automotive Electronicsandcharge/dischargeapplications -Line ConditionersandSolarChargeControllers.

**Textbooks:**

1. Ali Emadi, A. Nasiri and S. B. Bekiarov, “Uninterruptible Power Supplies and Active Filters”, CRC Press, 1st edition, 2005.
2. M. Ehsani,Y. Gao, E. G. Sebastien and A. Emadi, “Modern Electric, Hybrid Electric and Fuel Cell Vehicles”, Standards media, 2ndEdition,2009.

**Reference Books:**

1. William Ribbens, “Understanding Automotive Electronics”, BH, 8th edition, 2003.
2. N. Mohan, T.M. Undeland and W.P. Robbins, “Power Electronics Converters, Applications and design”, John Wiley and Sons, 3rd edition, 2007

| |
|---|
| 3. M. H. Rashid, "Power Electronics Circuits , Devices and Applications", Pearson publications, 3rd Edition, 2004 |
| **Online Learning Resources:** |

| Course Code | 21D21205 | POWERQUALITY (21D21205) (PE- IV) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | II | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

- To understand power quality definition, power quality standards.
- To remember measuring & solving power quality problems.
- To apply the various types of linear and nonlinear loads.
- To analyse harmonic methodology, mitigation techniques and case study.

**Course Outcomes (CO):** Student will be able to

**CO 1:** Understand the fundamentals & terminology of power quality.
**CO 2:** Apply the concept of power frequency disturbances, types of transients & transient waveforms.
**CO 3:** Analyze the harmonic methodology & Electromagnetic Interference concepts.
**CO 4:** Remember the necessity of grounding and methods of grounding.
**CO 5:** Understand different techniques of measuring & solving power quality problems.

**UNIT - I** | **INTRODUCTION TO POWERQUALITY** | Lecture Hrs: 10

Definition of Power Quality - Power Quality Progression - Power Quality Terminology - Power Quality Issues– Responsibilities of Power Suppliers and Users-Power Quality Standards.

**UNIT - II** | **POWER FREQUENCY DISTURBANCE&TRANSIENTS** | Lecture Hrs: 8

Introduction to Power Frequency Disturbance - Common Power Frequency Disturbances – Characteristics of Low Frequency Disturbances - Voltage Tolerance Criteria- ITIC Graph - Introduction to Transients -Transient System Model - Examples of Transient Models and Their Response - Power System Transient Modeling-Types and Causes of Transients -Examples of Transient Waveforms.

**UNIT - III** | **HARMONICS & ELECTRO-MAGNETIC INTERFERENCE (EMI)** | Lecture Hrs: 12

Definition of Harmonics - Harmonic Number (h) - Odd and Even Order Harmonics - Harmonic Phase Rotation and Phase Angle - Voltage and Current Harmonics - Individual and Total Harmonic Distortion -Harmonic Signatures - Effect of Harmonics On Power System Devices - Guidelines For Harmonic Voltage and Current Limitation - Harmonic Current Mitigation - Introduction to EMI - Frequency Classification –Electrical Fields-Magnetic Fields-EMI Terminology-Power Frequency Fields-High Frequency Interference-EMI Susceptibility-EMI Mitigation-Cable Shielding-Health Concerns of EMI.

**UNIT - IV** | **GROUNDINGANDBONDING** | Lecture Hrs:12

Introduction to Grounding and Bonding-Shock and Fire Hazards-NEC Grounding Requirements-Essentials of a Grounded System-Ground Electrodes-Earth Resistance Tests-Earth Ground Grid Systems-Power Ground System-Signal Reference Ground(SRG)-SRG Methods-Single and Multipoint Grounding –Ground Loops –Electro chemical Reaction -Examples of Grounding Anomalies.

| **UNIT - V** | **MEASURING AND SOLVING POWER QUALITY PROBLEMS** | Lecture Hrs:10 |
|---|---|---|
| Introduction to Power Quality Measurements-Power Quality Measurement Devices-Power Quality Measurements Test Locations-Test Duration-Instrument Setup- Instrument Guidelines | | |

**Textbooks:**

1. Power quality by C. Sankaran, CRC Press, 1st Edition, 2001.
2. Electrical Power Systems Quality, Roger C. Dugan, Mark F. McGranaghan, Surya Santoso, H. Wayne Beaty, 2nd Edition, TMH Education Pvt. Ltd, 1996.

**Reference Books:**

1. Understanding Power quality problems by Math H. J.Bollen IEEE Press, 1st edition, 2000.
2. Power quality enhancement using custom power devices by Arindam, Ghosh, Gerard Ledwich, Kluwer, Academic publishers, 1st edition, 2002.

**Online Learning Resources:**

| Course Code | 21D23205 | AITECHNIQUESINELECTRICALENGINEERING (21D23205) (PE-IV) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | II | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

- To locate soft commanding methodologies, such as artificial neural networks, Fuzzy logic and genetic Algorithms.
- To observe the concepts of feed forward neural networks and about feedback neural networks.
- To practice the concept of fuzziness involved in various systems and comprehensive knowledge of fuzzy logic control and to design the fuzzy control
- To analyze genetic algorithm, genetic operations and genetic mutations

**Course Outcomes (CO):** Student will be able to

- Understand feed forward neural networks, feedback neural networks and learning techniques.
- Applyselected basic AItechniques;judgeapplicabilityofmoreadvancedtechniques.
- Analyze&Develop fuzzy logic control for applications in electrical engineering
- Develop genetic algorithm for applications in electrical engineering.

**UNIT - I | ARTIFICIALNEURALNETWORKS | LecHrs: 10**

Introduction-Models of Neural Network - Architectures – Knowledge representation – Artificial Intelligenceand Neural networks – Learning process – Error correction learning – Hebbian learning – Competitivelearning – Boltzmann learning – Supervised learning –Unsupervised learning – Reinforcement learning –learningtasks.

**UNIT - II | ANN PARADIGMS | LecHrs: 9**

Multi – layer perceptron using Back propagation Algorithm-Self – organizing Map –Radial Basis FunctionNetwork–Functional link, network– Hopfield Network.

**UNIT - III | FUZZYLOGIC | LecHrs: 9**

Introduction – Fuzzy versus crisp – Fuzzy sets - Membership function – Basic Fuzzy set operations –Properties of Fuzzy sets – Fuzzy Cartesian Product – Operations on Fuzzy relations – Fuzzy logic – FuzzyQuantifiers-FuzzyInference- FuzzyRule basedsystem– Defuzzificationmethods.

**UNIT - IV | GENETICALGORITHMS | LecHrs: 10**

Introduction-Encoding– FitnessFunction-Reproductionoperators–Genetic Modeling –Genetic operators- Crossover- Single–site crossover –Two-pointcrossover–Multipointcrossover-Uniformcrossover–Matrixcrossover-CrossoverRate-Inversion&Deletion–Mutationoperator–Mutation–MutationRate-Bit-wiseoperators-Generationalcycle-convergenceofGeneticAlgorithm.

**UNIT - V | APPLICATIONSOF AITECHNIQUES | LecHrs: 10**

Load forecasting – Load flow studies – Economic load dispatch –Load frequency control – Single areasystem and two area system – Small Signal Stability (Dynamic stability) Reactive power control – speedcontrol ofDC and AC Motors.

**Textbooks:**

1. S.RajasekaranandG.A.V.Pai,"NeuralNetworks,FuzzyLogic&GeneticAlgorithms" PHI,New Delhi, 2nd edition,2017.

2. Sudarshan K. Valluru and T. NageswaraRao, "introduction to NeuralNetworks,FuzzyLogic&GeneticAlgorithms", Jaico Publishing House, 1st edition, 2010.

**Reference Books:**


1. P.D.Wasserman,VanNostrandReinhold," NeuralComputingTheory&Practice",NewYork, 1st . Eddition ,1989
2. BartKosko,"NeuralNetwork&FuzzySystem",PrenticeHall,1992.
3. G.J.KlirandT.A.Folger,"Fuzzy sets,UncertaintyandInformation", Pearson, 1st edition, 2015.
4. D.E.Goldberg, "GeneticAlgorithms", Pearson Education India, 1st edition, 2008.


**Online Learning Resources:**

| Course Code | 21D23206 | DIGITAL SIGNAL PROCESSORS AND APPLICATIONS (21D23206) (PE-IV) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | II | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

- Identify and describe the basic and advanced concepts of various DSP Processors.
- To use the basic and advanced concepts in order to develop various programmable based DSP applications.
- To explain the operation and performance of DSP based designs.
- To create DSP based controllers and processors for various simulation /real time based applications.

**Course Outcomes (CO):** Student will be able to

- Understand the basic and advanced concepts of different DSP Processors.
- Apply the basic and advanced concepts in order to develop various programmable based DSP applications.
- Analyze the operation and performance of DSP based designs for various real time issues.
- Design / create DSP based controllers and processors for various simulation /real time based applications.

| UNIT - I | DSP CONTROLLER TMSLF2407 | LecHrs: 10 |
|---|---|---|

Introduction to the TMSLF2407 DSP Controller- Brief Introduction to Peripherals - Types of Physical Memory-Software Tools.
C2XX DSP CPU and instruction set- Introduction to the C2xx DSP Core and Code Generation – The Components of the C2xx DSP Core - Mapping External Devices to the C2xx Core and the Peripheral Interface -System Configuration Registers –Memory -Memory Addressing Modes -Assembly Programming Using the C2xxDSP Instruction Set.

| UNIT - II | DATA TRANSFER AND COMMUNICATION | LecHrs: 9 |
|---|---|---|

Parallel and Serial Data Transfer- Pin Multiplexing(MUX) and General Purpose I/O Overview-Multiplexing and General Purpose I/O Control Registers - Using the General Purpose I/O Ports, Serial Communication.

| UNIT - III | DSP CONTROLLERTMS320LF24 | LecHrs: 9 |
|---|---|---|

Interrupt system of TMS320LF2407- Introduction to Interrupts - Interrupt Hierarchy - Interrupt Control Registers- Initializing and Servicing Interrupts in Software- real time control with interrupts.
The analog-to-digital converter (ADC)-ADC Overview- Operation of the ADC and programming modes.

| UNIT - IV | DSP CONTROLLER APPLICATIONS | LecHrs: 10 |
|---|---|---|

Event Managers (EVA, EVB)- Overview of the Event Manager (EV) - Event Manager Interrupts – General Purpose (GP) Timers- Compare Units - Capture Units and Quadrature Encoded Pulse (QEP) Circuitry –General Event Manager Information-PWM Signal Generation with Event Managers and interrupts, Measurement of speed with Capture Units, Implementation of Space Vector Modulation with DSPTMSLF2407A

| **UNIT - V** | **FIELD PROGRAMMABLE GATE ARRAY** | **LecHrs: 10** |
|---|---|---|
| Field Programmable Gate Arrays- Introduction to Field Programmable Gate Arrays – CPLD Vs FPGA –Types of FPGA , Configurable logic Blocks (CLB), Input/output Block (IOB) – Programmable Interconnect Point (PIP)- HDL programming –overview of Spartan 6 & ISE Design Suite, Implementation of PWM technique with SPARTAN-6 FPGA | | |
| **Textbooks:** | | |
| 1. HamidA.Tolyat,"DSPbasedElectromechanicalMotionControl", CRCpress,1st edition, 2004.<br>2. WayneWolf, "FPGAbasedsystemdesign",Prenticehall,1st edition, 2004. | | |
| **Reference Books:** | | |
| 1. ApplicationNotesfromthewebsiteofTexasInstruments<br>2. Spartan-6FPGAConfigurableLogicBlock,2010<br>3. XilinxSpartan6Datasheets | | |
| **Online Learning Resources:** | | |

| Course Code | 21D23207 | ELECTRIC DRIVES LAB (21D23207) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | II | | 0 | 0 | 4 | 2 |

**Course Objectives:** To make the student

- Understand and analyze torque speed characteristics of DC motors, 3 phase Induction Motor and PMSM with various converters connected.
- Apply and analyze various modulation techniques on different drives.
- Analyze performance of Induction Motors when different converters are connected.
- Analyze various types of drives when v/f control method are applied.

**Course Outcomes (CO):** Student will be able to

- To get practical training and hand on for the hardware and software application used in electric drives.
- To understand the practical problems and limitations of the methods used in electric drives.
- Apply and analyze various modulation techniques on different motor drives.
- Analyze performance of Induction Motors when different converters are connected.

**List of Experiments**:

1. Torque-SpeedcharacteristicsofDCmotor usingDC chopper.
2. Symmetrical anglecontrol of1-phaseACmotorconnectedtoACvoltagecontroller
3. Single-Phasedualconverterconnectedseparatelyexcited DC motordrive
4. Speed control of3-phase inductionmotorusingopen-loop V/fcontroltechnique
5. Torque-Speed characteristics of a 3-phase induction motor using IM-IMcomprehensivedrivesystem
6. StudyofaNeutral Point Clampedinverterfedthree-phaseinductionmotordrive
7. Pulsewidthmodulationcontrolof1-phaseACmotorconnectedtoACvoltagecontroller
8. Torque-Speedcharacteristicsofa3-phasePermanentMagnetSynchronousMotor(PMSM)usingPMSM-IMcomprehensivedrivesystem
9. Torque-speedcharacteristicsofaSeparatelyExcitedDCmotorDrivefedbyatwo-pulsecentre-tappedthyristorrectifier.
10. Torque-speedcharacteristicsofa6-pulsefullycontrolledrectifierfedSeparatelyExcitedDCmotorDrive
11. Studyofafour-quadrantSeparatelyexcitedDCmotordrivefedbydual-converterwithcirculatingcurrentcontrol
12. StudyClass-DcommutatedchopperfedSeparatelyExcitedDC motor Drive
13. Verification ofspectralperformanceofa3-PhVSIwith V/Hz control of3-Ph IMdrives
14. Torquespeedcharacteristicsofa 3-Phinduction motorfedby a3-PhVSI
15. ImplementationofcentrespacedspacevectormodulationwithDSPforV/Hzcontrolofinduction motordrives
16. ImplementationofdiscontinuousspacevectormodulationwithDSPforV/Hzcontrolofinduction motordrives

**Note:** Any ten experiments out of the list provided.

References:

| Course Code | 21D21209 | FACTS DEVICES & SIMULATION LAB (21D21209) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | II | | 0 | 0 | 4 | 2 |

**Course Objectives:** To make the student

- Understand how to write the coding in MATLAB/Mipower.
- Apply the SVC, STATCOM for voltage profile improvements & UPFC in power system networks.
- Analyze the data related to load flows incorporating SVC & STATCOM.
- Analyze operation of TCSC, STATCOM & SSSC for a transmission line fed by an AC supply.

**Course Outcomes (CO):**Student will be able to

**CO 1:** Understand Load balancing using compensators.
**CO 2:** Apply load balancing using Compenasators.
**CO 3:** Analyse load flow incorporating SVC & STATCOM.
**CO 4:** Develop a Simulation model for STATCOM & UPFC.

**LIST OF EXPERIMENTS**:

1. Voltage regulation using shunt and series compensation
2. Load balancing in power system network using compensators
3. Simulation of TCSC
4. Voltage profile improvement using SVC
5. Voltage profile improvement using STATCOM
6. Transient Stability enhancement using STATCOM.
7. Simulation of UPFC with mathematical models
8. Load flow incorporating SVC
9. Load flow incorporating STATCOM
10. Simulation of DVR
11. Transmission Line Characteristics (P vs δ, Q vs δ, P vs Distance, Q vs Distance and V vs Distance) with and without Compensation
12. Sizing- simulation and operation of TCR and FC-TCR for a transmission line fed by an ac supply and feeding
    (a) Resistive/inductive/capacitive load one at a time
    (b) A load which can have leading as well as lagging behaviour
13. Sizing- simulation and operation of TCSC for a transmission line fed by an ac supply

and feeding

(a) Resistive/inductive/capacitive load one at a time

(b) A load which can have leading as well as lagging behaviour

14. Sizing- simulation and operation of STATCOM for a transmission line fed by an ac supply and feeding

(a) Resistive/inductive/capacitive load one at a time

(b) A load which can have leading as well as lagging behavior

15. Sizing- simulation and operation of SSSC for a transmission line fed by an AC supply and feeding

(a) Resistive/inductive/capacitive load one at a time

(b) A load which can have leading as well as lagging behaviour

**Web Sources:** https://www.vlab.co.in

| Course Code | 21D23301 | CONTROL&INTEGRATIONOF RENEWABLEENERGYSOURCES (PE-V) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | III | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

1. A strong understanding of power systems, their operation and control focussed on the issues related to the integration of distributed renewable generation into the network.
2. To learn the principles of generating Heat Energy and Electrical energy from Non-conventional / Renewable Energy Sources.
3. To gain understanding of Control issues and challenges in various types of generators
4. Deep understanding about integration techniques for RE sources

**Course Outcomes (CO):** Student will be able to

1. Knowledge on different renewable energy sources and storage devices.
2. Recognize, model and simulate different renewable energy sources.
3. Analyze, model and simulate basic control strategies required for grid connection.
4. Implement a complete system for standalone/grid connected system

| UNIT - I | Introduction to Electric Grid | LecHrs: 9 |
|---|---|---|

Electric grid introduction, Supply guarantee and power quality, Stability, Effects ofrenewableenergypenetrationintothegrid,Boundariesoftheactualgridconfiguration,Consumptionmodelsandpatterns,staticanddynamicenergyconversiontechnologies,interfacingrequirements

| UNIT - II | DynamicEnergyConversionTechnologies | LecHrs: 9 |
|---|---|---|

Introductiontodifferentconventionalandnon-conventionaldynamicgenerationtechnologies,principleofoperationandanalysisofreciprocating engines, gas and micro turbines, hydro and wind based generation technologies,controlandintegratedoperationofdifferentdynamicenergy conversiondevices

| UNIT - III | StaticEnergyConversionTechnologies | LecHrs: 10 |
|---|---|---|

Introductiontodifferentconventionalandnon-conventional static generation technologies, principle of operation and analysis of fuel cell,photovoltaicbasedgenerators,andwindbasedgenerationtechnologies,differentstoragetechnologies such as batteries, fly wheels and ultra-capacitors, plug-in-hybrid vehicles, controlandintegratedoperationofdifferentstaticenergyconversiondevices

| UNIT - IV | Real and reactive power control | LecHrs: 10 |
|---|---|---|

Control issues and challenges in Diesel, PV, wind and fuelcellbasedgenerators,PLL,ModulationTechniques,Dimensionin go filters,Linearandnon-linearcontrollers,predictivecontrollersandadaptivecontrollers,Fault-ridethroughCapabilities,Load frequency andVoltageControl

| UNIT - V | Integration of different Energy Conversion Technologies | LecHrs: 10 |
|---|---|---|

Resources evaluation and needs,Dimensioningintegrationsystems,Optimizedintegratedsystems,Interfacingrequirements,integratedControlofdifferentresources,DistributedversusCentralizedControl,SynchroConverters,GridconnectedandIslandingOperations,stabilityandprotectionissues,loadsharing,Casesstudies

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY ANANTAPUR
JNTUA COLLEGE OF ENGINEERING (AUTONOMOUS) :: ANANTHAPURAMU
Ananthapuramu – 515 002, Andhra Pradesh, India

**R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES**
**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING**
**(POWER AND INDUSTRIAL DRIVES)**

| Textbooks: |
|---|
| 1. AliKeyhaniMohammadMarwaliandMinDai,"Integrationof Green andRenewableEnergyinElectricPowerSystem", JohnWileypublishingcompany, 1st edition, 2010.<br>2. S.Chowdhury,S.P.Chowdhury,P.Crossley,"MicrogridsandActiveDistributionNetworks",IET PowerElectronicsSeries,2012<br>3. G.Masters,"RenewableandEfficient Electric PowerSystems",IEEE-WileyPublishers, 2nd edition,2013. |
| **Reference Books:** |
| 1. Quing-ChangZhong,"ControlofPowerInvertersinRenewableEnergyandSmartGridIntegration",Wiley,IEEEPress, 1st edition, 2013.<br>2. BinWu,YongqiangLang,NavidZargari,"PowerConversionandControlofWindEnergySystems",Wiley- IEEE Press, 1st edition, 2011. |
| **Online Learning Resources:** |

| Course Code | 21D23302 | ENERGY STORAGE TECHNOLOGIES (PE - V) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | III | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

1. Understandgeneralizedstoragetechniques
2. Analyzethedifferentfeaturesofenergystoragesystems
3. Apply managementandapplicationsofenergystoragetechnologies
4. Knowabout electricalenergystoragemarket potentialbydifferentforecastingmethods

**Course Outcomes (CO):** Student will be able to

1. Understandtheroleofelectricalenergystoragetechnologiesinelectricityusage,hierarchy,demand forenergy storageandvaluationtechniques.
2. Analyzethebehaviorandfeaturesofelectricalenergy storagesystems
3. Apply energystoragesystem concepts to electric vehicles
4. Get knowledgeaboutenergystorageforecastingmethods

**UNIT - I THEROLESOFELECTRICALENERGYSTORAGETECHNOLOGIESINELECTRICITYUSE** — **LecHrs: 10**

Characteristicsof electricity,ElectricityandtherolesofEES,Highgenerationcostduringpeak-demandperiods,Needforcontinuousandflexiblesupply,Longdistancebetweengenerationandconsumption,Congestion in power grids, Transmission by cable, Emerging needs for EES, More renewableenergy,lessfossilfuel,SmartGriduses,Therolesofelectricalenergystoragetechnologies,Therolesfromtheviewpoint of a utility, The roles from the viewpoint of consumers, The roles from the viewpoint ofgeneratorsofrenewable energy.

**UNIT - II TYPESANDFEATURESOFENERGYSTORAGESYSTEMS** — **LecHrs: 10**

ClassificationofEESsystems,Mechanical storage systems, Pumped hydro storage (PHS), Compressed air energy storage (CAES),Flywheel energy storage (FES), Electrochemical storage systems, Secondary batteries, Lead-AcidBatteries, Lithium-Ion Batteries, Flow batteries, Other Batteries in Development, Chemical energystorage,Hydrogen($H_2$),Syntheticnaturalgas(SNG),Electricalstoragesystems,Double-layercapacitors(DLC),Superconductingmagneticenergystorage(SMES),Thermalstoragesystems,StandardsforEES,Technicalcomparison ofEEStechnologies.

**UNIT - III APPLICATIONS OF EES** — **LecHrs: 9**

Present status of applications, Utility use (conventional power generation,grid operation & service), Consumer use (uninterruptable power supply for large consumers), EESinstalled capacity worldwide, New trends in applications, Renewable energy generation, Smart Grid,SmartMicro grid,SmartHouse,Electricvehicles,

**UNIT - IV Management, Demand and Valuation of EES** — **LecHrs: 10**

MANAGEMENT AND CONTROL HIERARCHY OF EES: Internal configuration of battery storagesystems, External connection of EES systems, Aggregating EES systems and distributed generation(VirtualPowerPlant),“BatterySCADA”–aggregationofmany dispersed batteries.

DEMAND FOR ENERGY STORAGE:Growth in Variable Energy Resources, Relationship betweenbalancing services and variable energy resources, Energy Storage Alternatives, Variable GeneratorControl,DemandManagement,MarketMechanisms,and Longer TermOutlook.

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|---|---|---|
| VALUATIONTECHNIQUES:Overview,EnergyStorageOperationalOptimization,MarketPriceMethod, Power System Dispatch Model Method, Ancillary Service Representation, Energy StorageRepresentation,Surveyof Valuation Results. | | |
| **UNIT - V** | **FORECAST OF EES MARKET POTENTIAL BY 2030** | **LecHrs: 10** |
| EES market potential for overall applications,EES market estimation by Sandia National Laboratory (SNL), EES market estimation by the BostonConsulting Group (BCG), EES market estimation for Li-ion batteries by the Panasonic Group, EESmarketpotentialestimationforbroadintroductionofrenewableenergies,EES marketpotentialestimation for Germany by Fraunhofer, Storage of large amounts of energy in gas grids, EES marketpotentialestimationforEuropebySiemens,EESmarketpotentialestimationbytheIEA,Vehicletogridconcept, EES market potential in the future | | |
| **Textbooks:** | | |
| 1. PaulBreeze, “PowerSystemEnergyStorageTechnologies”,AcademicPress, 1st Edition, 2018.<br>2. AlfredRufer, “EnergyStorage:SystemsandComponents”, CRCPress, 1st edition, 2017. | | |
| **Reference Books:** | | |
| 1. Robert A. Huggins, “EnergyStorageFundamentals,MaterialsandApplications”,Springer, 2nd edition, 2015. | | |
| **Online Learning Resources:** | | |
| **1.** www.ecofys.com/com/publications | | |

| Course Code | 21D23303 | HYBRIDELECTRICVEHICLE ENGINEERING (PE-V) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | III | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

1. Understand thefundamentalconcepts,principles,analysis of hybrid electric vehicle
2. Analyze the performance, configuration and control of hybrid electric vehicles
3. Compare different energy management strategies
4. Designof battery electricvehicles

**Course Outcomes (CO):** Student will be able to

1. Understand of hybridelectricvehicles and differentenergystoragetechniques
2. Analyzetheadvantagesanddisadvantagesofhybridelectricvehiclesoverconventionalvehicles and meritsanddemeritsofhybridelectrictrainsoverelectricaltrains
3. Discusstheelectricpopulation,motordrivetechnologies
4. Designof battery electricvehicles

**UNIT - I INTRODUCTIONTOHYBRIDELECTRICVEHICLES — LecHrs: 9**

ConventionalVehicles:Basicsofvehicleperformance,vehiclepowersourcecharacterization,transmissioncharacteristics,andmathematicalmodels to describe vehicle performance. History of hybrid and electric vehicles, social and environmentalimportanceofhybridandelectricvehicles,impactofmodern drive-trains on energy supplies.

**UNIT - II HYBRID ELECTRIC DRIVE-TRAINS — LecHrs: 10**

Basic concept of electric traction, introduction to variouselectricdrive-traintopologies,powerflowcontrolinelectricdrive-traintopologies,fuelefficiencyanalysis. Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, powerflowcontrolinhybriddrive-traintopologies,fuelefficiencyanalysis.

**UNIT - III ELECTRIC PROPULSION UNIT — LecHrs: 10**

Introduction to electric components used in hybrid and electricvehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motordrives, configuration and control of Permanent Magnet Motor drives, Configuration and control of SwitchReluctanceMotordrives,drivesystemefficiency.

**UNIT – IV ENERGYSTORAGE — LecHrs: 9**

IntroductiontoEnergyStorageRequirementsinHybridandElectricVehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis,Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis,Hybridizationofdifferentenergystorage devices.

**UNIT - V ENERGY MANAGEMENT STRATEGIES — LecHrs: 10**

Introduction to energy management strategies used in hybridand electric vehicles, classification of different energy management strategies, comparison of differentenergy management strategies, implementation issues of energy management strategies. Case Studies:DesignofaHybridElectricVehicle(HEV),DesignofaBatteryElectricVehicle(BEV).

**Textbooks:**

1. IqbalHussein, "ElectricandHybridVehicles:DesignFundamentals",CRCPress, 3rd edition, 2021.
2. MehrdadEhsani, YimiGao, SebastianE. Gay, AliEmadi, "ModernElectric, HybridElectricandFuelCellVehicles:Fundamentals,TheoryandDesign",CRCPress, 2nd edition, 2009.
3. AliEmadi, "AdvancedElectricDriveVehicles",CRCPress,1st edition, 2017.

**Reference Books:**

1. JamesLarminie, JohnLowry, "ElectricVehicleTechnologyExplained", Wiley, 2nd edition, 2012.
2. SheldonS. Williamson,"EnergyManagement StrategiesforElectricandPlug-inHybridElectricVehicles",Springer,1st edition, 2013.

**Online Learning Resources:**

1. http://nptel.ac.in/syllabus/108103009

| Course Code | 21D20301 | WASTE TO ENERGY (Open Elective) | L | T | P | C |
|---|---|---|---|---|---|---|
| Semester | III | | 3 | 0 | 0 | 3 |

**Course Objectives:** To make the student

1. To understand the concept of waste to energy.
2. To analyze technical and management principles for production of energy from waste.
3. To apply the best available technologies for waste to energy.
4. To develop the process for thermal conversion, bio-chemical and waste to energy conversion.

**Course Outcomes (CO):**Student will be able to

**CO 1:** Understand the concept of waste to energy.
**CO 2:** Analyze technical and management principles for production of energy from waste.
**CO 3:** Apply the best available technologies for waste to energy.
**CO 4:** Develop the process for thermal conversion, bio-chemical and waste to energy conversion.

**UNIT – I | Introduction to Energy from Waste | Lecture Hrs: 9**

Classification of waste as fuel – Agro based – Forest residue – Industrialwaste– MSW– Conversiondevices–Incinerators – Gasifiers – Digestors.

**UNIT - II | Biomass Pyrolysis | Lecture Hrs: 9**

Pyrolysis – Types – Slow fast – Manufacture of charcoal – Methods – Yields andapplication– Manufacture ofpyrolytic oilsand gases – Yieldsand applications.

**UNIT - III | Biomass Gasification | Lecture Hrs: 10**

Gasifiers – Fixed bed system – Downdraft and updraft gasifiers – Fluidized bedgasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating –Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifieroperation.

**UNIT - IV | Biomass Combustion | Lecture Hrs: 10**

Biomass stoves – Improved challahs – Types, Some exotic designs – Fixed bedcombustors– Types – Inclined grate combustors – Fluidized bed combustors – Design – Construction andoperation– Operation ofallthe abovebiomasscombustors.

**UNIT - V | Introduction to Biogas | Lecture Hrs: 10**

Properties of biogas (Calorific value and composition)–Biogas plant technology and status – Bio energy system–Design and constructional features–Biomass resources and their classification– Biomassconversionprocesses–Thermochemicalconversion– Directcombustion– Biomassgasification– Pyrolysisandliquefaction– Biochemicalconversion– anaerobicdigestionTypesofbiogasPlants–Applications–Alcoholproductionfrombiomass– Biodieselproduction–Urbanwastetoenergyconversion – BiomassenergyprogrammeinIndia.

**Textbooks:**

1. Non-ConventionalEnergy,Desai,Ashok V.,WileyEasternLtd., 1st Edition,1990.
2. BiogasTechnology– APracticalHandBook- Khandelwal,K.C.andMahdi,S.S.,Vol.I&II,TataMcGrawHillPublishing Co.Ltd.,1st Edition,1983.

**Reference Books:**

1. Food,FeedandFuelfromBiomass,Challal,D.S.,IBHPublishingCo.Pvt.Ltd.,1st Edition,1991.
2. BiomassConversionandTechnology,C.Y.WereKo-

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| BrobbyandE.B.Hagan,JohnWiley&Sons,1st Edition,1996. |
| **Online Learning Resources:** |
| 1. https://www.digimat.in/nptel/courses/video/103107125/L01.html<br>2. https://nptel.ac.in/courses/103/107/103107125/ |