# M.TECH - POWER ELECTRONICS & DRIVES

## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Power Electronics plays an important role in processing and controlling the flow of electric energy by supplying voltages and currents in forms that are optimally suited for the user loads from a few watts to several megawatts. The application areas include wide spectrum such as Heating and Lighting Control, AC and DC Power Supplies, Electric Motor Control, Energy Conservation, Process Control and Factory Automation, Transportation, HVDC, FACTS Devices, Power Quality Improvement etc.

Power Electronics encompasses many fields within Electrical engineering.

The PG program includes courses in Mathematics, Cultural Education and the core subject areas. In core subject areas, emphasis is given on power processors with recent and emerging power switching devices, electrical machines and their control, measurement and processing of signals, signal processors, control systems and digital system design required to build any power electronic equipment with necessary controllers. The program offers electives for the students to enhance the knowledge of emerging machines, areas of power electronics applications and techniques to optimize the designs.

The Program culminates with a project work in which the students are encouraged to work on specific areas involving design, simulation, fabrication and testing of any power electronics system having research/industrial application values.

## CURRICULUM
### First Semester

| Course Code | Type | Course | L T P | Cr |
|---|---|---|---|---|
| 18MA609 | FC | Linear Algebra and Numerical Methods | 2 0 2 | 3 |
| 19PE601 | F C | Power Converters I | 3 0 2 | 4 |
| 19PE621 | FC | Electrical Machine Analysis | 3 1 0 | 4 |
| 19PE624 | SC | Electric Drive Systems | 3 1 0 | 4 |
| 19PE622 | SC | Advanced Control Theory | 3 0 0 | 3 |
| 19PE623 | SC | Simulation Lab | 0 0 2 | 1 |
| 19HU601 | HU | Amrita Values Program* | | P/F |
| 19HU602 | HU | Career Competency I* | | P/F |
| | | | Credits | **19** |

* Non-Credit Course

### Second Semester

| Course Code | Type | Course | L T P | Cr |
|---|---|---|---|---|
| 19PE603 | FC | Power Converters II | 3 0 2 | 4 |
| 19PE625 | FC | Advanced Electric Drives | 3 0 2 | 4 |
| 19PE626 | SC | Embedded Controllers | 3 0 2 | 4 |
| 19PE602 | FC | Digital Signal Processing Techniques | 3 0 2 | 4 |
| | E | Elective I | | 3 |
| | E | Elective II/Live-in-Labs | | 3 |
| 19RM600 | SC | Research Methodology | 2 0 0 | 2 |
| 19HU603 | | Career Competency II | 0 0 2 | 1 |
| | | | Credits | **25** |

### Third Semester

| Course Code | Type | Course | L T P | Cr |
|---|---|---|---|---|
| 19PE798 | P | Dissertation | | 8 |
| | | | Credits | **8** |

### Fourth Semester

| Course Code | Type | Course | L T P | Cr |
|---|---|---|---|---|
| 19PE799 | P | Dissertation | | 12 |
| | | | Credits | **12** |

**Total Credits: 64**

## List of Courses

### Foundation Core

| Course Code | Course | L T P | Cr |
|---|---|---|---|
| 19MA609 | Linear Algebra and Numerical Methods | 2 0 2 | 3 |
| 19PE601 | Power Converters I | 3 0 2 | 4 |
| 19PE602 | Digital Signal Processing  Techniques | 3 0 2 | 4 |
| 19PE603 | Power Converters II | 3 0 2 | 4 |

### Subject Core

| Course Code | Course | L T P | Cr |
|---|---|---|---|
| 19PE621 | Electrical Machine Analysis | 4 0 0 | 4 |
| 19PE622 | Advanced Control Theory | 3 0 0 | 3 |
| 19PE623 | Simulation Lab | 0 0 2 | 1 |
| 19PE624 | Electric Drive Systems | 3 1 0 | 4 |
| 19PE625 | Advanced Electric Drives | 3 0 2 | 4 |
| 19PE626 | Embedded Controllers | 3 0 2 | 4 |
| 19RM600 | Research Methodology | 2 0 0 | 2 |

| Electives | | | |
|---|---|---|---|
| **Course Code** | **Course** | **L T P** | **Cr** |
| 19ES624 | FPGA Based System Design | 2 0 2 | 3 |
| 19MA701 | Optimization Theory | 2 0 2 | 3 |
| 19PE701 | Modulation Techniques for Power Electronic systems | 3 0 0 | 3 |
| 19PE702 | Special Topics in Power Electronics | 3 0 0 | 3 |
| 19PE704 | Power Electronics for Electric Vehicle Applications | 3 0 0 | 3 |
| 19PE705 | Electrical Machine Analysis Using FEM | 3 0 0 | 3 |
| 19PE706 | Application of System Identification to Power Converters | 3 0 0 | 3 |
| 19PE707 | Modeling and Control of Power Converters | 3 0 0 | 3 |
| 19PE708 | Electric Vehicles and Architectures | 3 0 0 | 3 |
| 19PE709 | Programmable Logic Controllers | 3 0 0 | 3 |
| 19PE710 | Digital Control Systems | 3 0 0 | 3 |
| 19PE711 | Adaptive Control Systems | 3 0 0 | 3 |
| 19PE712 | Soft Computing | 2 0 2 | 3 |
| 19PE713 | Electric Power Quality Improvement | 3 0 0 | 3 |
| 19PE714 | FACTS and HVDC | 3 0 0 | 3 |
| 19PE715 | Energy Conservation and Management | 3 0 0 | 3 |
| 19PE716 | Power System Operation and Control | 2 0 2 | 3 |
| 19PE717 | Electromagnetic Interference and Compatibility | 3 0 0 | 3 |
| 19PE718 | Power System Modeling | 3 0 0 | 3 |
| 19PE719 | Design for Reliability | 3 0 0 | 3 |
| 19PE720 | Distributed Generation | 3 0 0 | 3 |
| 19RE708 | Smart Grid | 3 0 0 | 3 |
| 19PE722 | Renewable Energy Technologies | 3 0 0 | 3 |

**Project Work**

| Course Code | Course | L T P | Cr |
|---|---|---|---|
| 19PE798 | Dissertation | | 8 |
| 19PE799 | Dissertation | | 12 |

**19MA609 LINEAR ALGEBRA AND NUMERICAL METHODS 2-0-2-3**

**Course Objectives:**

- To understand the basic concepts of vector spaces, inner product spaces and apply to some problems in power systems and power electronics
- To understand and apply the iterative methods for various problems arise in the power electronics.

**Course Outcome(CO)**

| CO | Course Outcomes |
|---|---|
| CO1 | Understand the basic concepts of vector spaces, subspaces, linear independence, span, basis and dimension and analyze such properties on the given set. |
| CO2 | Understand the concept of inner products and apply it to define the notion of length, distance, angle, orthogonality, orthogonal complement, orthogonal projection, orthonormalization and apply these ideas to obtain least square solution. |
| CO3 | Understand the concept of linear transformations, the relation between matrices and linear transformations, kernel, range and apply it to change the basis, to get the QR decomposition, and to transform the given matrix to diagonal/Jordan canonical form. |
| CO4 | Understand the concept of positive definiteness, matrix norm and condition number for a given square matrix. |
| CO5 | Understand and apply numerical methods such as Power method for eigenvalues and numerical solutions of partial differential equations. |

**Vector Spaces**: General vector spaces - Sub spaces - Linear independence - Basis – Dimension-Row space, Column space and Null Space – Rank and Nullity.

**Inner Product Spaces**: Inner products - Orthogonality - Orthogonal basis - Orthogonal complements - Projection on subspace - Gram Schmidt Process - QR- Decomposition – Best approximation - Least square – Least squares fitting to data - Change of basis.

**Linear Transformations**: Linear transformation – General linear transformation - Kernel and range of a linear transformation - Inverse Linear Transformation - Matrices of general linear transformation- Nilpotent transformations - Similarity - Diagonalisation and its applications - Jordan form and rational canonical form - Positive definite matrices - Matrix norm and condition number.

**Numerical methods**: Solution of systems of equations – iterative methods, method of determining Eigen values and Eigen vectors by Power method. Numerical solution of partial differential equations – Elliptic, parabolic and hyperbolic equations.

**TEXT BOOKS / REFERENCES:**


1. Howard Anton and Chris Rorres, "*Elementary Linear Algebra*", Tenth Edition, John Wiley and Sons, 2010.
2. Gilbert Strang, "*Linear Algebra and Its Applications*", Fourth Edition, Cengage, 2007.
3. Kenneth Hoffmann and Ray Kunze, "*Linear Algebra*", Second Edition, Pearson, 2015.
4. Curtis F. Gerald and Patrick O. Wheatley, "*Applied Numerical Analysis*", Fifth Edition, Pearson, 2003.

**19PE601 POWER CONVERTERS I 3-0-2-4**

**Course Objectives:**

- To familiarize the characteristics of Power electronic devices, their data sheet interpretations.
- To learn performance parameters of various power converters
- To learn the design of ac-dc, dc-dc and dc-ac converters for various applications
- To learn the control of various power converter circuits.

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand and analyze the static and dynamic characteristics of fundamental power semiconductor devices, power modules and wide band gap devices |
| CO2 | Understand and analyze techniques to design and assess the performance of power converters such as AC-DC Converters, AC-AC converters and AC-DC inverters |
| CO3 | Assess power quality, power factor and harmonic issues of various power electronic converters |
| CO4 | Analyze PWM techniques for various converters |
| CO5 | Design, simulate, and test various power conversion circuits in the laboratory and their corresponding PWM techniques. (Lab component) |

Power semiconductor switches: ratings, characteristics, power loss and temperature rise calculations, and control (MOSFETS, IGBT, Thyristors, IPM, IGCT).Introduction to Wide Band Gap devices (SiC and GaN) and their applications AC voltage controllers- Line commutated, uncontrolled and phase controlled converters: Performance factors, Line notching and distortion. Twelve pulse converters. Introduction to Cyclo-converters, Matrix Converters. Voltage source inverters: single phase and three phase inverters. Sinusoidal PWM and Space vector PWM. Introduction to Finite set Model Predictive Control for power converters – Utility connected converters and their control. Multilevel inverters. UPS. Demonstration designs.

**TEXT BOOKS/ REFERENCES:**


1. Ned Mohan, Tore M. Undeland and William P.Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.
2. Muhammad H. Rashid, "*Power Electronics, Devices, Circuits and Applications*", Fourth Edition, Pearson, 2017.
3. John G. Kassakian, Martin F.Schlecht and George C.Verghese, "*Principles of Power Electronics*", Pearson, 2010.
4. Araújo, Samuel Vasconcelos, "*On the perspectives of wide-band gap power devices in electronic-based power conversion for renewable systems*", Vol. 3. Kassel university press GmbH, 2013.
5. Barry W Williams, "*Principles and Elements of Power Electronics Devices, Drivers, Applications, and Passive Components*", Barry W Williams, 2006.

**19PE621 ELECTRICAL MACHINE ANALYSIS 4-0-0-4**

**Course Objectives:**

- To learn steady state and dynamic modeling of DC and AC machines
- To introduce application of reference frame theory to AC machines

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Review of the basic principles of electro-mechanical energy conversion. |
| CO2 | Formulate the mathematical model of DC and AC Machines for transient and steady state conditions. |
| CO3 | Apply reference frame theory to AC machines. |
| CO4 | Analyze the dynamic behaviour of AC& DC machines. |
| CO5 | Explain the analytical model of PMSM and SRM |

Principles of electromagnetic energy conversion: General expression of stored magnetic energy, co-energy and force/torque, single and doubly excited system; Calculation of air gap mmf and per phase machine inductance, Three phase symmetrical induction machine and salient pole synchronous machines in phase variable form.

Generalized theory of rotating electrical machine and Kron's primitive machine; modeling, steady state and transient analysis of DC machines, Introduction to reference frame theory, Application of reference frame theory to three phase symmetrical induction and synchronous machines, modeling, steady state and transient analysis of induction machines, unbalanced operation and fault analysis in three phase induction motors. Steady state and transient analysis analysis of synchronous machines, standard and derived machine time constants, Analysis and dynamic modeling of two phase asymmetrical induction machine and single phase induction machine. , analysis of Permanent magnet machine and Switched reluctance machine.

**TEXT BOOKS/ REFERENCES:**


1. P.C.Krause, "*Analysis of Electric Machines and Drive Systems*", Wiley International, 2002.
2. T.A. LIPO, "Introduction to AC machine Design", Winsconsin Power Electronic Research Center", University of Winsconsin, 2011.
3. A.E. Fitzgerald and Charles Kingsley, "*Electric Machinery*", McGraw Hill Book Company, 2017.
4. B. Adkins, "*Generalized Machine Theory*", McGraw Hill Book Company, 1964.
5. Bimbhra P S, "*Electrical Machinery*", Khanna Publishers, 1995.


**19PE622 ADVANCED CONTROL THEORY 3-0-0-3**

**Course Objectives:**

- To analyze the LTI system in a state space framework.
- To design a state feedback controller and state observer.
- To understand and analyze the behavior of nonlinear systems.
- To gain an idea about the adaptive controllers and its applications.

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Review of linear system in state space approach |
| CO2 | Design state feedback controller, observer and optimal controller for linear systems |
| CO3 | Analyse non-linear system characteristics and its stability. |
| CO4 | Evaluate adaptive control techniques and parameter estimation of dynamic systems |

Review: Concept of state, state variables and state model, modelling is state space.
Control system design in state space: concept of controllability and observability. Pole placement techniques design using state feedback, design of state observers. Design of regulator systems with observer.Design of control systems with observer.Quadratic optimal regulator systems.
Non-linear systems: Introduction, behavior of non-linear system, common physical non linearity-saturation, friction, backlash, dead zone, relay, multi- variable non-linearity. Phase plane method, singular points, stability of nonlinear system, limit cycles, construction of phase trajectories. Liapunov stability criteria, Liapunov functions, direct method of Liapunov and the linear system, Hurwitz criterion and Liapunov's direct method, construction of Liapunov functions for nonlinear system.
Adaptive control: Closed loop and open loop adaptive control. Self-tuning controller, parameter estimation using least square and recursive least square techniques, gain scheduling, model reference adaptive systems (MRAS), self-tuning regulators.
Case study – Power Electronic Applications.

**TEXT BOOKS/ REFERENCES:**

1. Ogata, "*Modern Control Engineering*". Fifth Edition, Prentice Hall, 2009.
2. Franklin and Powell, "*Feedback Control of Dynamics Systems*". Seventh Edition, Pearson Hall, 2014.
3. David G. Luenberger, "*Introduction to Dynamic Systems: Theory, Models, and Applications*", Wiley, 1979.
4. Richard C. Dorf and Robert H. Bishop, "*Modern Control Systems*", Eleventh Edition Prentice Hall, 2008.
5. Karl J Astrom and Bjorn Wittenmark, "*Adaptive Control*", Addison –Wesley Series, 1995

**19PE623 SIMULATION LAB 0-0-2-1**

**Course Objectives:**

- To familiarize circuit level and system level simulation packages necessary for Power electronic system design
- To learn the methods of troubleshooting the simulation models
- To build power electronic simulation systems for various applications

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand the simulation tools MATLAB/Simulink, PSpice/OrCAD, PSCAD, for solving Electrical engineering problems related to power electronics |
| CO2 | Recognize various tool boxes used for power electronic application development. |
| CO3 | Examine the methods for Troubleshooting in various simulation tools. |
| CO4 | Implement and verify control strategies in the simulation platform for power electronic converters and electrical drives |

MATLAB/Simulink, OrCAD PSpice, PSCAD/EMTDC and EMTP for Power Electronics, Drives and Control applications.

**19PE602 DIGITAL SIGNAL PROCESSING TECHNIQUES 3-0-2-4**

**Course Objectives:**

- To familiarise the fundamental signal processing techniques
- To impart the concepts of Advanced Digital Filters, Multirate and Wavelets for electrical applications
- To comprehend the practical aspects of these topics in the electrical domain

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand digital processing techniques - DFT,FFT and Digital Filters applied to continuous time signals |
| CO2 | Apply advanced digital filters (Adaptive Filter and Kalman Filter) to address issues pertaining to electrical systems. |
| CO3 | Review the basic concepts of mutirate signal processing |
| CO4 | Apply discrete wavelets as filter banks in real time electrical networks |
| CO5 | Analyze advanced signal processing techniques to solve problems in electric domain |

Review of Sampling and aliasing, Discrete Fourier Transform, Fast Fourier Transform. Review of Digital Filters IIR Filters, FIR filters with MATLAB. Adaptive Filters (Four basic types), Discrete Kalman filters. Multirate Digital Signal Processing Basic Concepts.Introduction to Wavelet Transforms—Discrete Wavelet Transforms- Discrete Wavelets and Filter banks- Applications.

**TEXT BOOKS/ REFERENCES:**

1. Mitra S.K., "*Digital Signal Processing, A Computer-Based Approach*", McGraw Hill, 2002.
2. Ifeachor E. C. and Jervis B. W., "*Digital Signal Processing: A Practical Approach*", Addison Wesley, 1993.
3. Vaidyanathan P. P, "*Multirate Systems and Filter Banks*", Prentice Hall, 1993.
4. Simon Haykin, "*Adaptive Filter Theory*", Prentice Hall, 2001.
5. K.P.Soman,K.I.Ramachandran, N.G.Resmi, " *Insight into Wavelets*",Sixth Edition,PHI,2010

**19PE603** **POWER CONVERTERS II** **3-0-2-4**

**Course Objectives:**

- To design the non-isolated and isolated dc-dc converters and their operations in various modes
- To learn converter modeling
- To design controller for dc-dc converters
- To design the protection and magnetic circuits as applied for power converter system

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand and analyse dc-dc power converter circuits with and without isolation |
| CO2 | Analyse and design the operation of dc-dc converters in CCM and DCM modes |
| CO3 | Design of protection and magnetic circuits for power converters |
| CO4 | Develop mathematical models of dc-dc converters and the closed loop controllers |
| CO5 | Design, simulate, and test various dc-dc power conversion circuits in the laboratory and their corresponding PWM techniques. (Lab component) |

DC-DC converters: buck, boost, buck-boost, SEPIC, Multiport, fly-back, forward, push-pull, half bridge, full bridge converters, soft switched bidirectional DC-DC converters. Resonant/quasi resonant DC-DC converters, Concept of Wireless inductive and capacitive power transfer. Design of high frequency transformers and inductors-Drive and protection of switching power devices - voltage mode control and current mode control, modeling of the converters, Compensation of the feedback system for dc-dc converters. Single phase AC to DC converters with high power factor- Control of switch-mode converter for utility interface. Boost derived isolated DC-DC Converters – Typical specifications of power converters, design of power circuit to meet the specifications. EMI and Layout Fundamentals for switched mode circuits. Demonstration designs.

**TEXT BOOKS/ REFERENCES:**


1. Ned Mohan, Tore M. Undeland and William P.Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.
2. Robert W Erickson and DraganMaksimovic, "*Fundamentals of Power Electronics*", Springer International, 2001.
3. Daniel W Hart, "*Power Electronics*", Tata McGraw Hill, 2011.
4. John G. Kassakian, Martin F.Schlecht and George C.Verghese, "*Principles of PowerElectronics*", Pearson, 2010.
5. V. Ramanarayanan, "*Course Material on Switched Mode Power Conversion*", Department of Electrical Engineering, Indian Institute of Science, Bangalore.*http://minchu.ee.iisc.ernet.in/new/people/faculty/vr/book.pdf*

**19PE624 ELECTRIC DRIVE SYSTEMS 3-1-0-4**

**Course Objectives:**

- To introduce analysis of power electronics based control techniques for DC and AC machines
- To learn control techniques of special electric machines

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Review of the basic characteristics of a controllable drive |
| CO2 | Select a suitable motor rating for a particular drive application |
| CO3 | Illustrate the suitable control techniques for DC & AC drives. |
| CO4 | Investigate the vector and scalar control techniques for AC drives. |
| CO5 | Analyze the control of special electric machines. |

Introduction to Electric Drives – Need of electric drives, basic parts, present scenario of electric drives, Mechanical Dynamics in an Electric Drive - Speed-torque characteristics of some common motors and loads, multiquadrant operation, equivalent values of drive parameters, stability of an electric drive, General Block Diagram of a Closed Loop Drive System – Speed, torque and position control, Selection of Motor Power Rating – Thermal model of motor for heating and cooling, classes of motor duty, determination of motor rating

DC Motor Drive Using Phase Controlled Rectifier – DC motor drive using half controlled and fully controlled single phase and three phase rectifiers, continuous and discontinuous conduction modes of operation, 4-quadrantoperation using dual converter. Chopper Controlled DC Motor Drive – Different types of choppers and their quadrants of operations, PWM strategies for different choppers, chopper control of series DC motor.

Closed Loop Control of DC Motor – Operating limits of a separately excited DC motor drive, dynamic model of DC motor, dynamic model of chopper and phase controlled rectifier, design of single loop speed controller, cascaded controller design for DC motor using inner current control loop and outer speed control loop, field weakening operation.

Induction Motor Drive – Voltage Source Inverter and Current Source inverter based induction motor drives- Steady state equivalent circuit and phasor diagram with variable frequency supply, *v*/f control and constant air gap flux control of induction motor drive, field weakening operation of induction motor drive. Slip Power Recovery Systems, Static Kramer and Scherbius Systems

Synchronous Motor Drive – Synchronous motor drive with Variable Voltage Variable Frequency supply, synchronous motor drive using a voltage source inverter, synchronous motor drive using load commutated thyristor inverter, control of synchronous machine using cyclo converter.

**TEXT BOOKS/REFERENCES**

1. S.K. Pillai, “A First course on Electric Drives”, New Age Publishers, 2012
2. G.K Dubey, “Fundamentals of Electric Drives”, Narosa Publishing House, 2010
3. Krishnan R, “*Electric Motor Drives Modeling, Analysis and Control*”, Pearson, 2015.
4. Bimal K. Bose, “*Power Electronics and Variable Frequency Drives*”, Wiley IEEE Press, 2010
5. P. C. Sen, “Thyristor DC drives”, Krieger Publishing Company, 1991.

**19PE625 ADVANCED ELECTRIC DRIVES 3-0-2-4**

**Course Objectives:**

- To learn analysis and operation of DC and AC drives
- To develop control techniques of Multi quadrant drives

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Review of basic control techniques for electric drives. |
| CO2 | Illustrate modern control strategies in semiconductor drives. |
| CO3 | Analyze the control of special electric machines. |
| CO4 | Design a controlled drive for an Industrial application |

Induction Motor Drives: Field oriented control- Direct and indirect field orientation, stator-flux, and rotor-flux and air gap-flux orientation. Flux-torque decoupling, Extended speed operation and Field weakening.

Direct torque control of Induction Motor, Flux and speed observers, Induction generators, Doubly Fed Induction Machines (DFIM): Different modes of operation, Equivalent circuit, Active and reactive power control, Vector control of DFIM.

Identification of Induction Motor Parameters: Linear Model, Nonlinear least square identification, Parameter error indices. Speed sensor less control: Signal injection and model based techniques, zero/low speed operation.

Synchronous Motor Drives, Vector controlled Cyclo converter fed Drive, Parameter estimation and sensor less control.

Introduction to PM Synchronous Motor, Various rotor configurations of PMSM, Sinusoidal Back-Emf PMSM: Field oriented control, Direct torque control. Interior PM Machine: Maximum torque per ampere control, Field weakening

Introduction to Brushless DC Motor: EMF and Torque of BLDC machine, Voltage Source Inverter fed BLDC: Half-wave and Full-wave operation, Speed control, Torque ripple minimization, Sensor less operation.

Introduction to Switched Reluctance Motor

**TEXT BOOKS/REFERENCES**

1. Ion Boldea, Syed A Nasar, "*Electric Drives*", CRC Press, 2016.
2. De Doncker, Rik, Pulle, Duco W J, Veltman, Andre, "*Advanced Electrical Drives – Analysis, Modelling, Control*", Springer, 2011.
3. N.P.Quang, J.A.Dittrich, "*Vector Control of Three- Phase AC machines – System Development in the Practice*", Springer, 2008.
4. Krishnan R, "*Electric Motor Drives Modeling, Analysis and Control*", Pearson, 2015.
5. Bimal K. Bose, "*Power Electronics and Variable Frequency Drives*", Wiley IEEE Press, 2010.

**19PE6256 EMBEDDED CONTROLLERS 3-0-2-4**

**Course Objectives:**

- To comprehend a 16 bit microcontroller functions and operations
- To familiarize the interfacing modules of the controller
- To impart hands on experience with the controller for common electrical applications like PLL and SPWM.

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand the architecture of dsPIC30F3011 DSC |
| CO2 | Understand the working of various peripherals like ports ,timers, ADC,UART |
| CO3 | Develop C code for peripherals using MPLAB IDE. |
| CO4 | Implement application algorithms like PLL,SPWM and the like on c30 compiler |
| CO5 | Illustrate TMS320C2806x Piccolo DSP and Code Composer Studio for real world applications |

Architecture of dsPIC30F3011 DSC –C30 Compiler - Peripherals – Ports – Timers – Input capture – Output compare - ADC – MCPWM – QEI – UART. Application development in dsPIC30F3011 using C30 compiler - Implementation of PI controller, Filter algorithms, Clark and Park transformations, SPWM and SVPWM, PLL and Unit sine wave generation. Architecture of TMS320C2806x Piccolo DSP – Simple programs in Code Composer Studio.

**TEXT BOOKS/REFERENCES:**

1. dsPIC30F Programmers Reference Manual.
2. TMS320C2806x Piccolo Technical Reference Manual.
3. Andy Bateman and Iain Paterson-Stephens, "*The DSP Handbook, Algorithms, Applications and Design Techniques*", Prentice-Hall, 2002.
4. B Venkataramani and M Bhaskar, "*Digital Signal Processors: Architecture, Programming and Applications*", Tata McGraw Hill, 2002.

5. RulphChassaing, "*DSP Applications Using C and the TMS320C6x DSK*", John Wiley and Sons, 2002.

**19RM600 RESEARCH METHODOLOGY 2-0-0-2**

**Course Objectives:**

1. To familiarize with modeling, referencing, literature survey, etc
2. To design experiments and to analyse results of the experiments
3. To prepare technical reports and research papers
4. To prepare material for technical presentation and do oral presentation
5. To understand the purpose and terms of IPR
6. To orient to ethics in research and publication

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand types and methods of research, modeling, referencing, etc. |
| CO2 | Design experiments and analyse results |
| CO3 | Prepare and present research papers |
| CO4 | Aware of IPR and ethics |

Unit I:

Meaning of Research, Types of Research, Research Process, Problem definition, Objectives of Research, Research Questions, Research design, Approaches to Research, Quantitative vs. Qualitative Approach, Understanding Theory, Building and Validating Theoretical Models, Exploratory vs. Confirmatory Research, Experimental vs Theoretical Research, Importance of reasoning in research.

Unit II:

Problem Formulation, Understanding Modeling & Simulation, Conducting Literature Review, Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval, Tools for identifying literatures, Indexing and abstracting services, Citation indexes

Unit III:

Experimental Research: Cause effect relationship, Development of Hypothesis, Measurement Systems Analysis, Error Propagation, Validity of experiments, Statistical Design of Experiments, Field Experiments, Data/Variable Types & Classification, Data collection, Numerical and Graphical Data Analysis: Sampling, Observation, Surveys, Inferential Statistics, and Interpretation of Results

Unit IV:

Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript. References, Citation and listing system of documents

Unit V:

Intellectual property rights (IPR) - patents-copyrights-Trademarks-Industrial design geographical indication. Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work, Ethics in science

**TEXT BOOKS/ REFERENCES:**

1. Bordens, K. S. and Abbott, B. B., "Research Design and Methods – A Process Approach", 8th Edition, McGraw-Hill, 2011
2. C. R. Kothari, "Research Methodology – Methods and Techniques", 2nd Edition, New Age International Publishers
3. Davis, M., Davis K., and Dunagan M., "Scientific Papers and Presentations", 3rd Edition, Elsevier Inc.
4. Michael P. Marder, "Research Methods for Science", Cambridge University Press, 2011
5. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008
6. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age". Aspen Law & Business; 6 edition July 2012

**19PE701 MODULATION TECHNIQUES FOR POWER ELECTRONIC SYSTEMS 3-0-0-3**

Prerequisites: **POWER CONVERTER I**

**Course Objectives:**

- To familiarize various harmonic indices and harmonic analysis of converters
- To learn various PWM technique for inverters and multilevel inverters
- To design PWM schemes for reduced inverter losses

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Review of voltage source converters in inverter and rectifier mode of operation for various applications and Harmonic analysis of these converters |
| CO2 | Analyze various PWM techniques and their harmonic composition in voltage source converters and Multi level inverters. |
| CO3 | Implement various PWM techniques for rectifier and motor drive applications |
| CO4 | Analyze Inverter losses with various PWM techniques and their means of control |

Overview of applications of voltage source converter, motor drives, active front-end converters, reactive compensators, active power filters. Review of Fourier series, fundamental and harmonic voltages; machine model for harmonic voltages - line current distortion, increased losses, pulsating torque in motor drives. Control of fundamental voltage; mitigation of harmonics**.**
**S**elective harmonic elimination, THD optimized PWM, off-line PWM
Triangle-comparison based PWM: Average pole voltages, sinusoidal modulation, third harmonic injection, continuous PWM, bus-clamping PWM**,** Synchronously revolving reference frame - Space vector modulation, Per-phase and space vector approaches to over-modulation.
Line current ripple; hybrid PWM for reduced line current ripple**.** Relation between line-side

currents and dc link current - rms current rating of dc capacitors**.** Harmonic torques and RMS torque ripple, hybrid PWM for reduced torque ripple.
Inverter losses, influence of PWM techniques and switching frequency on switching losses, PWM for low inverter losses.
modulation method, compensation of dead-time effect.
PWM for multilevel inverter: Extensions of sine-triangle PWM to multilevel inverters, voltage space vectors, space vector based PWM, analysis of line current ripple and torque ripple.

**TEXT BOOKS/ REFERENCES:**

1. Dr. G. Narayanan, IISc, Bangalore, NPTEL Online Video course on "*Pulse width Modulation for Power Electronic Converters*" 2016.
2. Holmes, D. G., and Lipo, T. A., *Pulse Width Modulation for Power Converters: Principles and Practice* (Vol. 18). John Wiley and Sons, 2003.
3. Rodriguez, Jose, and Patricio Cortes, "Predictive *control of power converters and electrical drives*", Vol. 40. John Wiley & Sons, 2012
4. Ned Mohan, Tore M. Undeland and William P.Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.

**19PE702 SPECIAL TOPICS IN POWER ELECTRONICS 3-0-0-3**

**Course Objectives:**

- To familiarize various power devices and Power converters with special topologies
- To learn the design considerations of the special topology converters
- To learn the implementation of the special topology converters

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Review the characteristics of various Power Electronic Devices |
| CO2 | Understand the working principle of special converters viz. multi-pulse, zeta, multi-stepped, multilevel inverters, soft switched converters, resonant link converter and Z source converters. |
| CO3 | Analyze and design of all the special converters |
| CO4 | Implement the special converters and switched mode rectifiers |

Review of Power Electronic Devices.
Multi-pulse converters, Zeta converters, PWM inverters, Multi stepped inverters, Modular Multi level inverters, Neutral point controlled inverters, Soft switching converters: DC-DC resonant link inverters, Hybrid resonant link inverters, Quasi resonant link converters, Z-source inverters, PV inverter topologies, Switched mode rectifiers, Synchronous link converters.

**TEXT BOOKS/ REFERENCES:**

1. Ned Mohan, Tore M. Undeland and William P.Robbins, "*Power Electronics, Converters, Applications and Design*", Third Edition, John Wiley and Sons Inc., 2006.
2. Muhammad H. Rashid, "*Power Electronics, Circuits, Devices and Applications*", Fourth Edition, Pearson, 2017.

3. Erickson, Robert W., and Dragan Maksimovic, "*Fundamentals of power electronics*", Springer Science & Business Media, 2nd Edition, 2007.
4. Liu, Yushan, Haitham Abu-Rub, Baoming Ge, and Omar Ellabban, "*Impedance source power electronic converters*", John Wiley & Sons, 2016.

**19PE704 POWER ELECTRONICS FOR ELECTRIC VEHICLE APPLICATIONS 3-0-0-3**

**Course Objectives:**

- To introduce operation of Electric Vehicle drive trains
- To learn different propulsion motors used in EVs
- To learn energy storage systems used in EV and its management

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand an Electric Vehicle Architecture |
| CO2 | Familiarise drive trains and analyse power flow |
| CO3 | Identify various propulsion motors used in EVs |
| CO4 | Illustrate different Energy storage systems and management |
| CO5 | Understand the design of a HEV and BEV |

Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance. Conventional Vehicles: Basics, characterization, transmission, mathematical models.
Electric Drive-trains: Introduction, power flow control, fuel efficiency analysis, Hybrid Electric Drive. Electric Propulsion: Introduction, Configuration and control of different types of motors in drive trains, drive system efficiency, impact of modern drive-trains on energy supplies.
Energy Storage: Introduction, Requirements, Analysis, Battery, Super Capacitor, Fuel cell, Fly wheel. Energy Management Strategies: Introduction, classification, implementation issues of energy management strategies.
Case Studies: Design of a Hybrid Electric Vehicle (HEV), Design of a Battery Electric Vehicle (BEV)

**TEXT BOOKS/ REFERENCES:**

1. Haitham Abu-Rub, Mariusz Malinowski, Kamal Al-Haddad, "*Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications*", Wiley Publishers, June 2014.
2. Chris Mi; M. Abul Masrur and David Wenzhong Gao, "*Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives*", Wiley Publishers, Jun 2011
3. Yangsheng Xu, Jingyu Yan, Huiihuan Qian and Tin Lun Lam, "*Hybrid Electric Vehicle Design and Control: Intelligent Omni directional Hybrids*", Mc-Graw Hill Education, 2014.
4. Bruno Scrosati, Garche and Werner Tillmetz, "*Advances in Battery Technologies for Electric Vehicles*", Woodhead Publishing Series in Energy.
5. Ehsani, Mehrdad, Yimin Gao, Stefano Longo, and Kambiz Ebrahimi, "*Modern electric, hybrid electric, and fuel cell vehicles*", CRC press, 2018.

**19PE705 ELECTRICAL MACHINE ANALYSIS USING FEM 3-0-0-3**

**Course Objectives:**
- To learn basic principles of Finite Element Analysis
- To apply Finite Element Analysis to Electric Machines

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand the basic principles of finite element method. |
| CO2 | Analyze two dimensional problems using finite element method. |
| CO3 | Determine the electromagnetic parameters of electrical apparatus |
| CO4 | Design of electrical machines using FEM software tool |

Review of Electromagnetic theory, basic principles of finite element method, applications of finite element method to two dimensional fields, linear interpolation, variational method, description of electromagnetic fields, analysis procedure using finite element method, reduction of field problem to a two dimensional problem, boundary conditions, drawing flux line, magnetic energy and co-energy, magnetic forces, determination of electrical parameters.
Cylindrical magnetic devices, analytical study of magnetic devices, finite element analysis, single phase transformer, computation of no load inductance, determination of leakage inductance, algorithm for the construction of magnetizing characteristics of a transformer.
Single phase variable reactance, computation of reactance. Design using any FEM tool

**TEXT BOOKS /REFERENCES:**

1. Nicola Bianchi, "*Electrical Machine Analysis Using Finite Elements*", CRC Press, 2005.
2. Cheng D K, "*Fundamentals of Engineering Electromagnetic*", Addison Wesley, 1993.
3. Reece A and Preston T, "*Finite Element Method in Electric Power Engineering*", Oxford University Press, UK, 2000.

**19PE706 APPLICATION OF SYSTEM IDENTIFICATION TO POWER CONVERTERS 3-0-0-3**

**Course Objectives:**
- To design and estimate parametric models of power converters
- To develop adaptive controllers for power converters

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Identify various techniques for system identification |
| CO2 | Design and Estimate parametric models |
| CO3 | Develop dynamic models for non-parametric identification |
| CO4 | Introduce various adaptive control techniques to control systems |
| CO5 | Apply system Identification techniques to Power Electronic systems |

Introduction and overview of Systems Identification, Parametric model structures; Linear regression problem; Least Squares formulation and its variants. Maximum Likelihood Estimation; Estimation of non-parametric models; Notions of prediction and simulation.
Estimation of parametric models - prediction error methods and instrumental variable methods. Model structure selection and diagnostics. Dynamic models, ARMA, ARMAX. Estimation theory, least squares, generalized least squares, instrumental variables, prediction error methods. Non parametric identification, Sub space identification, Identification with prediction error methods prediction model structure.

Adaptive control, Model Reference Adaptive Control (MRAC), Basic adaptive control schemes, open loop adaptive control, direct and indirect adaptive control, Adaptive regulation, Parameter adaptation algorithm. Self-Tuning Regulators (STR), Different approaches to self-tuning regulators – Stochastic Adaptive control – Gain Scheduling
System identification of power converters based on a black-box approach

**TEXT BOOKS /REFERENCES:**


1. K. J. Astrom and B. Wittenmark, Adaptive Control, Addison - Pearson, 2006.
2. L. Ljung, System Identificaiton: Theory for the user, Prentice -Hall, 2007.
3. T. Soderstrom and P. Stoica, System Identification, Prentice Hall, 1989.
4. Arun K. Tangirala, Principles of System Identification: Theory and Practice, CRC Press 2014
5. Sastry, S. and Bodson, M., "Adaptive Control– Stability, Convergence and Robustness", Prentice Hall inc., New Jersey, 1989.


**19PE707 MODELLING AND CONTROL OF POWER CONVERTERS 3-0-0-3**

**Course Objectives:**

- To learn state space modeling of Power Converters
- To develop controllers for voltage regulation of Power Converters

**Course Outcomes:**

| | |
|---|---|
| CO1 | Understand the concept of state space modelling and analysis of Rectifiers, dc-dc converters, multi input dc-dc converters and their control |
| CO2 | Design state feedback controllers and observers for rectifiers, dc-dc converters and multi input dc-dc converters. |
| CO3 | Analyse the rectifier and dc-dc converter circuits under continuous and discontinuous current mode of operation |
| CO4 | Implement various controllers for voltage regulation of rectifiers, dc-dc converters and multi-input dc-dc converters |

State space modeling and control of single phase and three phase rectifiers - State feedback controllers and observer design for output voltage regulation - Analysis of continuous and discontinuous mode of operation.
State space modeling and control of Buck, Buck-Boost, Cuk, Sepic, Zeta Converters - Analysis and closed loop voltage regulations using state feedback controllers and sliding mode controllers.
Modeling of multi input DC-DC converters and state feedback controllers for output voltage regulation - applications

**TEXT BOOKS /REFERENCES:**


1. Sira -Ramirez, R.SilvaOrtigoza, "*Control Design Techniques in Power Electronics Devices*", Springer, 2006.
2. Siew-Chong Tan, Yuk-Ming Lai, Chi Kong Tse, "*Sliding mode control of switching Power Converters*", CRC Press, 2011.
3. Erickson, Robert W., and Dragan Maksimovic, "*Fundamentals of power electronics*", Springer Science & Business Media, 2nd Edition, 2007.
4. Bimal Bose, "*Power electronics and motor drives*", Elsevier, 2006.

5. Ion Boldea and S.A Nasar, "*Electric drives*", CRC Press, 2005.

**19PE708 ELECTRIC VEHICLES AND ARCHITECTURES 3-0-0-3**

**Course Objectives:**

- To understand Configuration and Types of EV, HEV Drivetrains
- To learn design of Hybrid Electric Vehicle

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Review standards, drive cycles, impacts, economy of Electric Vehicles |
| CO2 | Illustrate architecture of Electric Vehicle and Hybrid Electric Vehicles |
| CO3 | Analyse control of Power converter and motor in Electric Vehicles |
| CO4 | Understand battery testing , maintenance and monitoring techniques |

Introduction to electric vehicles (EVs): Historical perspective. EV advantages and impacts. EV market and promotion: infrastructure needs, legislation and regulation, standardization, Drive cycle, Functions electronically controlled in automotive.

Importance of energy efficiency / emission norms and fuel efficiency: Assessing economy of electric vehicles, Fuel economy V's fuel consumption V's GHG (Green House Gas) emissions

Important electrical subsystem in vehicles: Basic components of a hybrid vehicle, Types of hybrids, Migration from 12V to 48V systems, Start/Stop Hybrid architecture types (BSG(Belt start Generator) /ISG(Integrated Starter Generator )), EV architectures

EV architectures - Parallel Hybrid/ Series Hybrid (Range Extended Hybrid) Architectures: Hybrid electric vehicles (HEVs): types, operating modes, torque coordination and control, generator/motor requirements

Introduction to power converter and motor control: Case study

On-board/off-board chargers (V2H, V2G concepts): Battery parameters. Types and characteristics of EV batteries. Battery testing and maintenance; charging schemes. Battery monitoring techniques. Open-circuit voltage and ampere-hour estimation. Battery load leveling.

**TEXT BOOKS /REFERENCES:**

1. Iqbal Husain, "*Electric and Hybrid Vehicles, Design Fundamentals*", CRC PRESS, published in the Taylor & Francis e-Library, 2005.
2. K. T. Chau, "*Electric Vehicle Machines and Drives Design, Analysis and Application*", IEEE, John Wiley and Sons, 2015.
3. Austin Hughes and Bill Drury, "*Electric Motors and Drives, Fundamentals, Types and Applications*", $4^{th}$ Edition, Elsevier, 2013.
4. James Larminie, John Lowry, "*Electric Vehicle Technology Explained*", John Wiley and Sons, 2003.

5. C.C. Chan and K.T. Chau, "*Modern Electric Vehicle Technology*", Oxford University Press, 2001.

**19PE709 PROGRAMMABLE LOGIC CONTROLLERS 3-0-0-3**

**Course Objectives:**
1. To introduce the working of PLC and its interface.
2. To study the basics of ladder logic programming.
3. To understand the PLC data organization and instruction set.

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand the fundamentals of PLC and Ladder diagram |
| CO2 | Illustrate the working of Digital and Analog PLC interface |
| CO3 | Describe the PLC processor Data Organization and programming instructions |
| CO4 | Able to work on a real time problem |

Introduction to PLC-Ladder diagram-relay logic-digital and analogy PLC interface-input and Output modules-PLC processors-processor data organization- basic relay instruction-timer and counter instruction-sequencer instruction-programme flow instruction- case studies-motor control.

**TEXT BOOKS / REFERENCES:**
1. Dunning Carry, "*Introduction to Programmable Controllers*", Third Edition, Thomson Delmar Learning, 2006.
2. John R. Hackworth and Frederick D, "*Programmable Logic Controllers: Programming Methods and Applications*", Pearson Education Inc., 2004.
3. Bolton W, "*Programmable Logic Controllers*", Fifth Edition, Elsevier, 2009.
4. John W Webb and Ronald A Reis, "*Programmable Logic Controllers: Principles and Applications*", Fifth Edition, PHI learning Pvt. Ltd., 2009.
5. Frank D.P., "*Programmable Logic Controllers*", Second Edition, Tata Mc Graw Hill Publishing Company Limited, 1997.

**19PE710 DIGITAL CONTROL SYSTEMS 3-0-0-3**

**Course Objectives:**

- To understand the sampling process and signal reconstruction.
- To characterize the discrete-time systems in z-domain and frequency domain.
- To design a digital controller using root locus and frequency response methods.
- To design the lag and lead compensators
- To design a state feedback controller and observer.

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Review of Z-transform, sampling and reconstruction of signals. |
| CO2 | Analyse stability of linear system in Z-domain |
| CO3 | Design compensators in time and frequency domains and transform to Z-domain |
| CO4 | Design digital controllers and observers in Z domain. |

Review of Z-transforms. Pulse transfer function. Digital control system: sampling, quantization, data reconstruction and filtering of sampled signals. Z-transform analysis of closed loop and open loop systems, Stability analysis of closed loop systems in the z-plane: frequency domain analysis, stability tests. Discrete equivalents. Digital controller design for

SISO systems: design based on root locus method in the z-plane, design based on frequency response method, design of lag compensator, lead compensator, lag lead compensator, design of PID Controller based on frequency response method, direct design. Controllability, Observability, control law design, decoupling by state variable feedback, effect of sampling period. Estimator/ Observer Design: full order observers, reduced order observers, regulator design.

**TEXT BOOKS/ REFERENCES:**

1. Gene F. Franklin, J. David Powell and Michael Workman, "*Digital Control of Dynamic Systems*", Pearson, 2000.
2. Benjamin C Kuo, Farid Golnaraghi, "Automatic Control Systems", Eighth Edition, Wiley, 2014.
3. K. Ogata, "*Discrete-Time Control Systems*", Pearson Education, 2011.
4. Moudgalya, "Digital Control", First Edition, Wiley Publication, 2008.
5. C. L. Philips, Troy Nagle, Aranya Chakrabortty, "*Digital Control System Analysis and Design*", Prentice-Hall, 2014.

**19ES624 FPGA BASED SYSTEM DESIGN 2-0-2-3**

**Course Objectives:**

- To introduce the design flow of FPGA and different abstraction levels of HDL for FPGA design
- To design combinational and sequential circuits for FPGA realizations

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Realization of combinational logic circuits in circuit level and using PLDs |
| CO2 | Design combinational logic circuits using HDL |
| CO3 | Design sequential logic circuits using HDL |
| CO4 | Understand the design styles in different FPGA architectures |
| CO5 | Synthesize digital circuits in FPGAs |

HDL – Role of HDL - VHDL for Design Synthesis - Design Flow – Programmable logic:Simple PLDs, CPLDs, FPGA VHDL - Entities and Architectures - A Simple Design – Design Entities – VHDL elements - Data flow – behavioural – structural modeling – Creating Combinational and Synchronous Logic - Designing FIFO - Test Benches - State Machine Designs - Design Examples - Memory Controller - Mealy State Machines – Design Considerations - Hierarchy in Large Designs - Functions and Procedures – Subprograms - General principles of circuit synthesis - Synthesis and Design Implementation - Synthesis and Fitting CPLDs, FPGAs - Optimizing Data paths – Pipelining - Resource Sharing - Creating Test Benches – Implementation technology – PLD's, Custom Chips, Standard Cell and Gate arrays – FPGA Architectures – SRAM based FPGAs – Permanently programmed FPGAs – Circuit design of FPGA fabrics – Architecture of FPGA fabrics – Logic Implementation of FPGAs - Physical design for FPGAs

**TEXT BOOKS / REFERENCES:**

1. Kevin S kahill, "*VHDL for Programmable Logic*", Pearson Education, 1996.
2. Stephen Brown and Zvonko Vranesic, "*Fundamental of Digital Logic with VHDL Design*", Third Edition, McGraw Hill, 2017.
3. Douglas L Perry, "*VHDL Programming by Example*", Fourth Edition, Tata Mc Graw Hill, 2002.

4. Wayne Wolf, "*FPGA-Based System Design*", Prentice Hall India Pvt. Ltd., 2004.
5. Samir Palnitkar, "*Verilog HDL - A Guide to Digital Design and Synthesis*", Second Edition, Pearson Education, 2003.

**19PE711 ADAPTIVE CONTROL SYSTEMS 3-0-0-3**

**Course Objectives:**

- To understand the concept of adaptive control systems.
- To analyze the various adaptive control schemes
- To analyze the design approach of self-tuning regulators.
- To gain an idea about predictive control and parameter estimation

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand the basics of adaptive control system. |
| CO2 | Discuss the various adaptive control techniques. |
| CO3 | Analyse convergence of multivariable adaptive controllers. |
| CO4 | Illustrate the adaptive controllers and parameter estimation. |

Introduction to adaptive control**,** Classifications, Role of Index performance (IP) in adaptive systems

Model Reference adaptive systems: Different configurations, Classification, Mathematical Description, Equivalent representation as a time varying system, Direct and indirect MRAC, Continuous time MRAC, MIT Rule, Lyapunov approach, Stability and convergence studies.

Self Tuning Regulators (STR), Different approaches to self tuning, Recursive parameter estimation, Pole placement design; linear quadratic self - Tuning regulators; Convergence analysis, multivariable self tuning regulators, pole assignment approach. Introduction to Predictive Control; Minimum variance Control; State Estimation. Application of Adaptive controllers

**TEXT BOOKS/ REFERENCES:**

1. K. J. Astrom and B. Witten mark, "*Adaptive Control*", Second Edition, Dover Publications, 2008.
2. P. A. Ioannou and J. Sun, "*Robust Adaptive Controls*", Dover Publications, 2012
3. S. Sastry and M. Bodson, "*Adaptive Control*", Dover Publications, 2011 (available now at http://www.ece.utah.edu/%7Ebodson/acscr/index.html)
4. M. Krstic, I. Kanellakopoulos, and P. Kokotovic, "*Nonlinear and Adaptive Control Design*", Wiley-Inderscience, 1995.
6. V.V.Chalam, "Adaptive Control Systems, Techniques and Applications", Taylor and Francis Group, 1987.

**19PE712 SOFT COMPUTING 2-0-2-3**

**Course Objectives:**

- To learn different soft computing techniques
- To introduce application of evolutionary algorithms to optimization problems
- To learn solution of real time problems using soft computing

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Apply neural networks to pattern classification and regression problems |
| CO2 | Solve engineering problems with uncertainty using fuzzy logic technique |
| CO3 | Apply evolutionary algorithms for optimization problems. |
| CO4 | Apply software tools to solve real time problems by soft computing techniques. |

Fuzzy Logic (FL) – Membership Functions – Fuzzifications and Defuzzifications – Fuzzy Relations – TSK Fuzzy Modeling. Neural Networks (NN) – Supervised and Unsupervised Learning – Hopfield – RBF Networks Kohonen Self Organizing Networks – Learning Vector Quantization – Hebbian Learning.
Neuro-fuzzy models- adaptive neuro-fuzzy inference system (ANFIS)- Architecture – Hybrid Learning Algorithm – Learning Methods that Cross-fertilize ANFIS and RBFN - Applications.
Genetic Algorithms— Random Search – Downhill Simplex Search.
Introduction to Support Vector Machines – Classification and Regression – Typical Applications Integrating Various Soft Computing Tools.

**TEXT BOOKS/ REFERENCES:**

1. Timothy Ross, "*Fuzzy Logic with Engineering Applications*", Second Edition, John Wiley and sons, 2004.

2. Simon Haykin, "*Neural Networks and Learning Machines*", Third Edition, Pearson Education, 2009.
3. K.F. Man, K.S. Tang and S. Kwong, "*Genetic Algorithms: Concepts and Applications*", IEEE

Transactions Industrial Electronics, Vol-3,1996.

4. Jan Komorowski, Lech Polkowski and AndrzejSkowron, "*Rough Sets: A Tutorial*",

http://Folli.Loria.Fr/Cds/1999/Library/Pdf/Skowron.Pdf

**19PE713 ELECTRIC POWER QUALITY IMPROVEMENT 3-0-0-3**

**Course Objectives:**

- To learn sources, effects of Power Quality Issues
- To learn Power Quality Improvement Techniques

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand sources and effects of various power quality issues. |
| CO2 | Analyse the behaviour of power quality events and categorise them based on the recommended standards |
| CO3 | Judge, design and develop suitable mitigation techniques |
| CO4 | Analyse the performance of power quality improvement schemes |

Review of power quality issues-Voltage sags and swells, interruptions, transients, notches, unbalance, distortions, fluctuations and flicker. IEEE Recommended Practices and Requirements

for Harmonic Control in Electric Power Systems 519-1992, Recommended Practices for Individual Consumers – Recommended Practices for Utilities - Causes and effects of power quality issues, Measurements. Harmonic studies: Circuit analysis and power assessment under non-sinusoidal conditions- Symmetrical components- Harmonic propagation studies in large network- FFT Analysis.
Power Quality Improvement techniques: Passive filters – Review - Harmonic and Reactive power compensation – Design, Active Filters – Review - Active filter control schemes/algorithms- Time domain and frequency domain - Instantaneous reactive power theory (IRPT) algorithm, Synchronous Detection (SD) algorithm, DC Bus voltage algorithm, Synchronous reference frame (SRF) algorithm, Icosϕ algorithm, AI based control algorithms, Analog/digital implementation - Case studies. Hybrid Filters –Review – Design -Applications - Estimation of rate/cost reduction with hybrid filters. Review of single-phase and three-phase improved power quality converters - Applications. Custom power parks -Custom power devices and Applications. Power Quality issues in Distributed Generation.

**TEXT BOOKS/ REFERENCES:**

1. J.Arillaga, N.R.Watson and S.Chen, "*Power System Harmonics*", John Wiley and Sons, England, 2005.
2. Enrique Acha and Manuel Madrigal, "*Power Systems Harmonics-Computer Modeling and Analysis*", John Wiley and Sons Ltd., 2001.
3. George J. Wakileh, "*Power Systems Harmonics-Fundamentals, Analysis and Filter Design*", Springer-Verlag, New York, 2007.
4. Ewald and Mohammad Masoum, "*Power Quality in Power Systems and Electrical Machines*", Elseveir Academic Press, 2008.
5. Bhimsingh, Ambrish Chandra, Kamal Al-Haddad, *"Power Quality Problems and Mitigation Techniques*", John Wiley&Sons Limited, 2015.

**19PE714 FACTS AND HVDC 3-0-0-3**

**Course Objectives:**

- To learn application of Power Electronic Devices in Transmission and Distribution Systems
- To understand operation and control of Various Power line Compensators
- To introduce design principles of Power Electronic Converters that helps in controlling Voltage Profile, Active and Reactive Power Flows.

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand the basic concepts, principles and operation of power system compensators |
| CO2 | Design suitable corrective measures for performance improvement of power lines |
| CO3 | Analyse effective control strategies for power line compensators |
| CO4 | Analyse the performance of corrective equipments under different operating scenarios |

Review of AC Transmission: Power flow - Loading capability - Principle of Compensators- FACTS concept and types of FACTS controllers, IEEE definitions.
Shunt compensators: Objectives of shunt compensation, Variable impedance Devices (TSR, TCR, TSC, FC-TCR, TSC-TCR), Switched converter (STATCOM) and Hybrid shunt

compensators.
Series compensators: Concept of series capacitive compensation, Variable impedance Devices (GCSC, TSSC, TCSC), Static Synchronous Series Compensators (SSSC). Control schemes for different applications.
Static voltage and phase angle regulators: Concepts of power flow control, Transient stability, Power oscillation damping with series and shunt compensation.
Introduction to UPFC.
High Voltage DC Transmission: Comparison with AC System, HVDC configurations,unipolar and bipolar links, components of HVDC system - Converter, transformer, smoothing reactor, harmonic filter. Reactive power support, operation of 6-pulse, 12 Pulse Converters in rectifier and inverter modes. Effect of source inductance, equivalent circuit representation. Control of HVDC system.

**TEXT BOOKS/ REFERENCES:**

1. Narain G. Hingorani and Laszlo Gyugyi, " *Understanding FACTS – Concepts and Technology of Flexible AC Transmission Systems*", IEEE Power Engineering Society, 2011.
2. R.Mohan, Mathur and Rajiv. K. Varma, "*Thyristor Based FACTS Controller for Electrical Transmission System, IEEE Series on Power Engineering*", Wiley Interscience, 2011.
3. Padiyar K. R, "*FACTS Controllers in Power Transmission and Distribution*", New Age Publishers, 2007.
4. K R Padiyar, "HVDC Power Transmission Systems – Technologies and System Interactions", New Age International (P) Limited, 2007.
5. Chan – Ki – Kim, Vijay K Sood,Gil – Sood, Gil – Soo Jang, Seong –JooLim,Seok – Jim – Lee, "HVDC Transmission Power Conversion Applications in Power Systems", Wiley – IEEE Press, April 2009

**19PE715 ENERGY CONSERVATION AND MANAGEMENT 3-0-0-3**

**Course Objectives:**

- To understand energy scenario and policies of India & world
- To analyse energy efficiency of various technologies and evaluate techno-economic feasibility of various improvement opportunities using a systematic auditing methodology.

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand and analyse energy scenario & policies of India & World in the past, present & future |
| CO2 | Understand the energy efficiency performance indicators of various technologies and methodologies to evaluate the indices. |
| CO3 | Evaluate the Techno economic feasibility of various efficiency improvement opportunities for an existing system |
| CO4 | Understand the methodology of energy auditing through case studies |

Historical development of commercial energy supply**:** Commercial energy in ancient times, Renewable Energy utilization in ancient times, Industrial revolution, Growth of fossil fuel systems, Emergence of nuclear power, Realization of environmental concerns, Developments in Renewable Energy Sector; Concept of Energy Efficiency and Clean Production.
Energy conservation on demand side: Efficient Lighting; Energy Efficiency in motors, pumps and fans. Power quality issues related to Energy Efficient Technologies.
Energy Economics**:** Time value of money - Present Worth and Future Worth Economic performance indices: Payback - Simple and Discounted, Net Present Value, Internal Rate of Return, Benefit to Cost Ratio, E/D ratio, Life cycle/levelised cost.

Energy Management in Electrical Power Systems**:** Supply-demand gap on electric power grid: causes and remedial measures. Energy trading; Demand Response; Microgrids and Smart grid. Energy Management and Audit: Functions and methodologies of preliminary as well as detailed energy audits; Pre-audit, audit and post-audit measures Instruments for energy audit, Energy Conservation Practice – Case Studies**.**

**TEXT BOOKS / REFERENCES:**

1. Hamies, "*Energy Auditing and Conservation; Methods, Measurements, Management and Case Study*", Hemisphere Publishers, Washington, 1980.
2. C.W. Gellings and J.H. Chamberlin, "*Demand-Side Management Planning*", Fairmont Press, 1993.
3. Wayne C Turner, "*Energy Management Handbook*", The Fairmount Press, 2006.
4. Bureau of Energy Efficiency Study material for Energy Managers and Auditors Examination: Paper I to IV, www.energymanagertraining.com
5. S. Pabla, "*Electric Power Systems Planning*", Macmillan India Ltd., 1998.

**19PE716 POWER SYSTEM OPERATION AND CONTROL 2-0-2-3**

**Course Objectives:**

- To learn operation and control of power system components
- To introduce modeling and design of power system components

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand the operating states of power system and various factors related to load variations. |
| CO2 | Analyze Automatic Generation and Voltage Control loops in power systems. |
| CO3 | Design components to control voltage and frequency in power system. |
| CO4 | Evaluate the performance of control loops using modern software tools. |
| CO5 | Compute economic load dispatch for load frequency control. |

Introduction- System load Variation: System load characteristics, Load curve- weekly and annual duration curve, load factor, diversity factor. System State and Transition, Operation of vertical and deregulated power system, Control center functions. Overview of system control: Governor control, LFC, AVR. Linear Models of Synchronous machines- Transient stability- Dynamic Stability. Real power- frequency control: Need for voltage and frequency regulation in power system, basic P-f and Q-V control loops. Fundamentals of speed governing systems and modeling, LFC of Single area and two area systems. Modeling of single and two area system - Power System Stabilizers. Reactive power – Voltage control: Typical excitation system, static and dynamic analysis, effect of generator loading, static shunt capacitor/reactor VAR compensator, synchronous condenser, tap changing transformer, Static VAR system, modeling, system level voltage control.

**TEXT BOOKS/ REFERENCES:**

1. Olle.I.Elgerd, "Electric Energy Systems Theory- An Introduction", Tata Mc Graw Hill Publishing company Ltd., New Delhi, 2004.

2. William D Stevenson, "Elements of Power System Analysis", 4th Edition, McGrawHill, 2017.

3. Allen.J. Wood and Bruce.F.Wollenberg, "Power Generation Operation and Control", John Wiley and Sons, 2006.

4. L.K.Kirchmayer, "Economic Operation of Power System", John Wiley and Sons, 2009.

5. P. Kundur, "Power System Stability and Control", Mc Graw Hill, 2006.

## 19PE717 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY 3-0-0-3

**Course Objectives:**

- To learn the concepts of electromagnetic interference and electromagnetic compatibility
- To understand electromagnetic interference control techniques
- To introduce electromagnetic interference measurements and standards

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand the basics of Electromagnetic Interference and its sources |
| CO2 | Understand the non-ideal behavior of electrical components |
| CO3 | Illustrate the conducted and radiated emissions and susceptibility |
| CO4 | Analyse EMI reduction techniques |
| CO5 | Apply EMI standards and techniques |

Problems of EMI and Sources – ESD – High Frequency behavior of Electrical Components-EMI in Power Electronic Equipments – EMI induced failure mechanism in PE Equipment – Susceptibility aspects of power Electronic and Digital Equipments – Noise Suppression in Circuits – Reduction Techniques for Internal EMI – EMI reduction techniques – Grounding, Shielding and Bonding, use of cables connectors components, EMI filter selection, Filter design, Testing for susceptibility to power line disturbances, transient susceptibility and analysis methods, EMC standards and test equipments.

**TEXT BOOKS/REFERENCES:**

1. Laszio Tihanyi, "*EMC in Power Electronics*", IEEE Press, 1995.

2. V.Prasad, "*Engineering Electromagnetic Compatibility*", IEEE Press, 2001.

3. Henry W.Ott, "*Noise Reduction Techniques in Electronic Systems*", Second Edition, John Wiley and Sons Ltd., 1988.

4. Rajiv Thottappillil, Lecture Notes on EMC, KTH ,Stockholm.

**19MA701** **OPTIMIZATION THEORY** **2--0-2-3**

**Course Objective:**

- To Understand and apply various optimization techniques to solve the problems arise in the power electronics.

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand different types of Optimization Techniques in engineering problems such as Bracketing, Region elimination, and Point estimation methods. |
| CO2 | Analyse gradient based Optimizations Techniques in single variables as well as multivariables (non-linear). |
| CO3 | Understand the Optimality criteria for functions in several variables and apply OT methods like Undirectional search and Direct search methods. |
| CO4 | Analyse constrained optimization techniques and verify Kuhn-Tucker conditions and Lagrangian Method. |

Review of Linear Algebra: Linear programming models: Simplex search — sensitivity analysis – artificial starting solutions - duality and sensitivity in linear programming. Single variable optimization: Analytical method: Optimality criteria. Single variable non-linear problems using derivatives. Computational Methods: Non-linear one-dimensional methods – single variable optimization algorithms – optimization criteria – bracketing methods – region elimination methods – point estimation method – gradient based methods. Multivariable optimization: Analytical method: Positive and negative definite, Hessian matrix, Optimality criteria. Multivariable non-linear problems using partial derivatives. Computational Methods: Non-linear unconstrained methods - multivariate optimization algorithms – optimality criteria – unidirectional search – direct search methods – gradient based methods. Constrained optimization: Non–linear constrained methods – Kuhn-tucker conditions – transformation methods – direct search for constrained minimization – feasible direction method

**T EXT BOOKS/ REFERENCES**

1. Kalyanmoy Deb, "*Optimization for Engineering Design: Algorithms and Examples*", Prentice Hall, 2002.
2. Ronald L. Rardin, "*Optimization in Operations Research*", Prentice Hall, New Jersey, 1998.
3. Singiresu S. Rao, "*Engineering Optimization: Theory and Practice*", Third Edition, New Age Publishers, 2003.
4.Hamady A. Taha, "*Operations Research*", Sixth Edition, Tata McGraw Hill, 2004.
5. E. Clapton, "Advanced Optimization Techniques and Examples with MATLAB" CreateSpace Independent Publishing Platform,2016

**19PE718** **POWER SYSTEM MODELING** **3-0-0-3**

**Course Objectives:**

- To learn modeling of various power system components and power electronics devices used in power system.
- To introduce static and dynamic performance analysis of power systems

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand the Models of nonelectrical components generally used in power system |
| CO2 | Develop transformer and synchronous machine models |
| CO3 | Develop models of Power Electronic devices used in Transmission lines |
| CO4 | Analyse static and dynamic performance of power systems with FACTS |

Modelling of Power System Components: classical methods of modeling. Simplified models of non-electrical components like boiler, steam, hydro-turbine, diesel engine and governor system. Transformer modelling - auto-transformer, tap-changing and phase-shifting transformers. Modelling of Transmission line and Loads.

Modelling of Excitation system: definitions of voltage response ratio and exciter voltage ratings. IEEE excitation systems. Excitation configurations- dc and ac excitations, self and separately excited systems. Basics of Park's transformation. Modelling of Synchronous machine: Basic flux linkage, voltage and torque equations of synchronous machine - Basics of Park's transformation. The current & flux linkage models using Park's transformation - Models for steady-state and dynamic studies. Simulation and analysis of Synchronous machine connected to an infinite bus. Modelling of Power converters, Modelling of wind and solar power plants. Modelling of FACTS devices, Stability analysis of sample power system models.

**TEXT BOOKS/ REFERENCES:**

1. K.R.Padiyar, "*Power Systems Dynamics*", B.S. Publications, 2008.
2. Anderson and Fouad, "*Power System Control and Stability– Vol. I*", IEEE Press, New York, 1994.
3. Kundur, "*Power System stability and Control*", McGraw Hill, 1994.
4. Krishna, S," *An Introduction to Modelling of Power System Components*", Springer, 2014.
5. Qiuwei Wu, Yuanzhang Sun, "*Modeling and Modern Control of Wind Power*", IEEE press, John Wiley & Sons Ltd, 2018.
6. **Sen**, Zekai,*"Solar Energy Fundamentals and Modeling Techniques", Springer, 2008.*

**19PE719 DESIGN FOR RELIABILITY 3-0-0-3**

**Course Objectives:**

1. To familiarize with concepts of reliability
2. To learn reliability modeling using statistical techniques
3. To compute reliability indices and identify testing components
4. To apply reliability theory in engineering design

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand the basic concepts of reliability. |
| CO2 | Analyze the statistical techniques leading to reliability modelling. |
| CO3 | Identify reliability indices and testing components. |
| CO4 | Apply reliability theory in engineering design. |

Review of Probability theory – Introduction to the concepts of Reliability – Nature of Reliability problems in Electronic equipment – Reliability modeling – Availability and maintability concepts – Designing for Reliability – Fault Analysis techniques – Reliability predictions – Worst case design and component de-rating – software Reliability.

**TEXT BOOKS / REFERENCES:**

1. Fuqua, "*Reliability Engineering for Electronic Design*", Marcel Dekker, 1988.
2. Patrick DTO'Connor, "*Practical Reliability Engineering*", John Wiley and Sons, 2008.
3. MIL Handbook-338 – "*Reliability of Electronic Equipment*".
4. L.Umanand, "*Power Electronics Essentials and Applications*", Wiley India Pvt. Ltd., 2009.

**19PE720 DISTRIBUTED GENERATION 3-0-0-3**

**Course Objectives:**

- To familiarize the concept of distributed generation and its techniques
- To learn the concept of renewable power generation and energy storage
- To design interfacing power electronics converters for distributed generators
- To design microgrids with multiple generators and energy storage
- To familiarize the policies and regulations for distributed generation

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand the background of promotion of DG and compare DG with centralised generation |
| CO2 | Possess technical and general knowledge on wind, PV and hybrid systems |
| CO3 | Able to design power electronic interfaces in DG systems |
| CO4 | Able to design micro grid system with energy storage |
| CO5 | Understand policies and regulations |

Comparison of legacy grid and microgrid. Distributed Generation –historical background, current status, policy and regulations, challenges – issues related to bidirectional power flow.

Renewable energy systems – solar PV, wind, small hydro and biomass based electric power generation – system design.Hybrid systems - wind-solar, wind - PV-hydro.Standalone systems with energy storage -sizing of battery storage.

Power converters for PV systems – Grid tied and grid forming modes, active power control in grid connected PV system.

Power converters for wind turbine generators – Powerconverter topologies for PMSG, DFIG and VSIG, - Dual converters with DC-link capacitance, grid synchronization and phase locking, control

ofrotor side and grid side converters, design of filter, maximum power tracking and active power control. Islanded condition.
Dynamic control of power - Bidirectional converter and control for battery storage system, Variable speed operation of pumped hydro storage; use of real time data for distributed generation control.

**TEXT BOOKS/ REFERENCES:**

1. Loi Lei Lai, Tze Fun Chan, "Distributed *Generation-Induction and Permanent Magnet Generators*", IEEE Press, 2007.
2. Haitham Abu-Rub, Mariusz Malinowski, Kamal Al-Haddad, "*Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications*", Wiley Publishers, June 2014.
3. Massey, G. W., *Essentials of distributed generation systems*. Jones and Bartlett Learning, 2010.
4. Bollen, M. H., and Hassan, F., *Integration of distributed generation in the power system* (Vol. 80). John Wiley and Sons, 2011.

**19RE708 SMART GRID 3-0-0-3**

**Course Objectives:**

1. To be aware of the significance and requirements of smart grid
2. To familiarize with communication technologies and real time monitoring schemes
3. To learn phasor and frequency estimation
4. To familiarize with standards and regulations for SG
5. To design smart solutions for power systems

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand power system operations, issues with existing system and capabilities of Smart Grid (SG) |
| CO2 | Analyse the scope of distributed generation and Demand side management in SG |
| CO3 | Apply phasor, frequency estimation algorithms |
| CO4 | Compare and evaluate communication technologies for SG |
| CO5 | Develop smart strategies for power system issues |

Smart grid definition. Smart grid vs. conventional grid. Smart Grid technologies- Power system and information communication technology (ICT) in Generation, Transmission and Distribution.
Basic understanding of power systems. Evolution of power electronics in power system applications. Smart Grid features (Distributed generation, storage, Demand dispatch(DD),Demand Response(DR),Advanced Metering Infrastructure (AMI),Wide Area measurement system(WAMS),wide area control system(WACS).
Sensors - CT, PT; Devices –Intelligent Electronic Devices (IED),Phasor measurement unit(PMU),phasor data concentrator( PDC), relays, DR Switch ;Communication- Standards, Technology and protocols.
Control Capabilities of Power Electronic converters for Smart Grid- Grid tied operation, Islanded operation and Grid forming mode. Impact of the uncertainties of Renewable energy on the smart grid stability and need for reliable/effective smart grid communication. Impact of Plugged in EV/HEV on Smart grid demand profile.
Case Study - Smart microgrid simulator (SMGS), DR, DD, Energy storage, Smart Appliances.

**TEXT BOOKS/ REFERENCES:**

1. James Momoh, "*Smart Grid: Fundamentals of Design and Analysis*", Wiley-IEEE Press, March 2012.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu and Akihiko Yokoyama, "*Smart Grid:Technology and Applications*", Wiley, February 2012.
3. Ali Keyhani and Muhammad Marwali, "*Smart Power Grids 2011*", Springer, 2011.
4. Mini S. Thomas, John Douglas McDonald,"*Power System SCADA and Smart Grids*", CRC Press, April 2015.
5. Qing Chang Zhong, Tomas Hornik- "*Control of Power Inverters in Renewable Energy and Smart Grid Integration*" -Wiley-IEEE Press 2013.

**19PE722 RENEWABLE ENERGY TECHNOLOGIES 3-0-0-3**

**Course Objectives:**

1. To familiarize with national and global policies and scenarios of RE development
2. To learn basics and characteristics of solar energy as well as PV systems
3. To learn wind energy resource assessment and wind power conversion
4. To learn methods of energy conversion related to other RE sources like biomass, small hydro, tides, wave, ocean thermal energy, etc.

**Course Outcomes (CO)**

| | |
|---|---|
| CO1 | Understand the need and means for renewable energy utilisation |
| CO2 | Understand the schemes to produce electricity from renewable resources |
| CO3 | Assess renewable energy potential availability |
| CO4 | Analyse the characteristics and control of various RE energy conversion systems |
| CO5 | Design of system for various renewable energy extraction schemes |

Renewable energy sources: Renewable energy utilization in ancient times; classification of RE technologies – stand alone, hybrid and grid-connected; Recent developments in renewable energy sector – global and national energy policies

Wind energy – Global and local winds, resource assessment, wind regime modeling – Weibull parameters; WEG technologies for grid connection.

Solar energy – Solar radiation and measurements; PV Cell – principle, types and construction; Modeling of PV cell; Maximum power tracking; SPV systems – stand alone and grid-connected.

Other renewable energy technologies: Biomass – gasifiers; Small hydro – resource assessment, selection of turbines, Electronic load controller; Wave, Tidal, Ocean thermal and Geothermal energy systems – principles and technologies; Energy storage systems.

**TEXT BOOKS / REFERENCES:**

1. Thomas B Johansson, "*Renewable Energy: Sources for Fuels and Electricity*", Island Press, Washington, 1993.
2. John W Twidell and A D Weir, "*Renewable Energy Resources*", Routledge Publications, 2015.
3. N K Bansal, M Kleemann and M Mellis, "*Renewable Energy Resources and Conversion Technology*", Tata McGraw Hill, 1990.
4. S N Bhadra, D Kastha and S Banerji, "*Wind Electrical Systems*", Oxford University Press, 2005.

**19PE798/ 19PE799 DISSERTATION 8/12**

**Course Objectives:**

1. To review the literature and formulate a research problem
2. To develop skill in use of computational and analytical tools
3. To carry out the investigation and analyse the observations
4. To communicate the findings orally as well as in writing
5. To familiarize with project management

**Course Outcomes (CO)**

| | | |
|---|---|---|
| 19PE798 Dissertation | CO1 | Understand research methodology |
| | CO2 | Plan and execute Projects |
| | CO3 | Survey and review literature |
| | CO4 | Choose computational and analytical tools and design experiments |
| | CO5 | Communicate technical content orally as well as in writing with added skill |
| 19PE799 Dissertation | CO1 | Plan and manage projects with skill |
| | CO2 | Analyse results and acquire domain knowledge |
| | CO3 | Use computational and analytical tools with skill |
| | CO4 | Demonstrate skill in technical communication |
| | CO5 | Comprehend and disseminate knowledge |

Each student should select and work on a topic related to his/her field of specialization during summer of second semester under the supervision of a faculty member.

During third and fourth semester each student should work on the selected topic under the supervision of a faculty member. By the end of each (third and fourth) semester the student has to prepare a report in the approved format and present it.