**SYLLABUS STRUCTURE**

**FOR**

**TWO-YEAR M. TECH. PROGRAMME**

**IN**

**POWER ELECTRONICS & DRIVES**



|  |
| --- |
| **NAAC – A Grade** |

**DEPARTMENT OF ELECTRICAL ENGINEERING**

**COLLEGE OF ENGINEERING & TECHNOLOGY**

**(An Autonomous and Constituent College of BPUT, Odisha)**

**Techno Campus, Mahalaxmi Vihar, Ghatikia,**

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**COURSE: M. Tech. (EE – Power Electronics & Drives), Duration: 2 years (Four Semesters)**

**Abbreviations Used: U= UG, I= Integrated, P= PG**

**PC= Professional Core PE= Professional Elective OE= Open Elective**

**LC= Lab Course MC= Mandatory Course AC= Audit Course**

**L= Lectures P= Practical/Laboratory IA\*= Internal Assessment**

**T= Tutorial PA= Practical Assessment EA=End-Semester Assessment**

**\*Internal Assessment Max. Mark (30 marks) consists of Mid Semester (20 marks) and Quiz+Assignment (10 marks)**

**Subject Code Format:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **Prog (U/I/P)** | **Type (PC/PE/OE/LC/MC/AC)** | | **Department (CE/EE/IE/ME/…)** | | **Semester (1/2/…/0)** | **Serial No. (1/2/3/…/99)** | |

**1st SEMESTER**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Subject**  **Type** | **Subject Code** | **Subject**  **Name** | **Teaching Hours** | | | **Credit** | **Maximum Marks** | | | |
| **L** | **T** | **P** | **IA** | **EA** | **PA** | **Total** |
| 1 | Core 1 | PPCEE103 | Power Electronic Converters | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 2 | Core 2 | PPCEE104 | Electric Drives | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 3 | Professional Elective 1  (Any One) | PPEEE103 | Solar Photovoltaic Systems | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPEEE104 | Storage Technology |
| 4 | Professional Elective 2  (Any One) | PPEEE105 | FACTs & Custom Power Devices | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPEEE106 | Advanced Control Systems |
| 5 | Mandatory | PMCMH101 | Research Methodology & IPR | 2 | 0 | 0 | 2 | 30 | 70 | - | 100 |
| 6 | Lab 1 | PLCEE102 | Power Electronics Lab | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| 7 | Lab 2 | PLCEE103 | Power Electronics Simulation Lab | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| **Total** | | | | **14** | **0** | **8** | **18** | **150** | **350** | **200** | **700** |
| 8 | Audit 1 | Any one subject from Appendix-I | | | | | | | | | 100 |
| **Grand Total** | | | | | | | | | | | **800** |

**2nd SEMESTER**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Subject**  **Type** | **Subject Code** | **Subject**  **Name** | **Teaching Hours** | | | **Credit** | **Maximum Marks** | | | |
| **L** | **T** | **P** | **IA** | **EA** | **PA** | **Total** |
| 1 | Core 3 | PPCEE203 | Advanced Power Electronic Converters | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 2 | Core 4 | PPCEE204 | Modeling, Analysis & Control of Electric Drives | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 3 | Professional Elective 3  (Any One) | PPEEE202 | AI & Machine Learning | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPEEE203 | Programmable Embedded Systems |
| 4 | Professional Elective 4  (Any One) | PPEEE206 | Smart Grid Technology | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPEEE208 | Power Quality |
| 5 | Practical 1 | PPREE201 | Mini Project with Seminar | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| 6 | Lab 3 | PLCEE203 | Electrical Drives Lab | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| 7 | Lab 4 | PLCEE204 | Embedded Systems Lab | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| **Total** | | | | **12** | **0** | **12** | **18** | **120** | **280** | **300** | **700** |
| 8 | Audit 2 | Any one subject from Appendix-II | | | | | | | | | 100 |
| **Grand Total** | | | | | | | | | | | **800** |

**3rd SEMESTER**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Subject Type** | **Subject Code** | **Subject**  **Name** | **Teaching Hours** | | | **Credit** | **Maximum Marks** | | | |
| **L** | **T** | **P** | **IA** | **EA** | **PA** | **Total** |
| 1 | Professional Elective 5  (Any One) | PPEEE301 | Grid Integration of Renewable Sources | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPEEE303 | Modelling and Simulation |
| PPEEE304 | Electric and Hybrid Vehicles |
| 2 | Open Elective | Any one subject from Appendix-III | | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 3 | Project 1 | PPREE301 | Phase-I Dissertation | 0 | 0 | 20 | 10 | - | - | 100 | 100 |
| **Total** | | | | **6** | **0** | **20** | **16** | **60** | **140** | **100** | **300** |

**4th SEMESTER**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Subject Type** | **Subject Code** | **Subject**  **Name** | **Teaching Hours** | | | **Credit** | **Maximum Marks** | | | |
| **L** | **T** | **P** | **IA** | **EA** | **PA** | **Total** |
| 1 | Project 2 | PPREE401 | Phase-II Dissertation | 0 | 0 | 32 | 16 | - | - | 100 | 100 |
| **Total** | | | | **0** | **0** | **32** | **16** | **-** | **-** | **100** | **100** |

**Abstract of Credit and Marks Distribution**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sl. No.** | **Semester** | **Maximum Credits** | **Maximum Marks** |
| 1 | 1st Semester | 18 | 800 |
| 2 | 2nd Semester | 18 | 800 |
| 3 | 3rd Semester | 16 | 300 |
| 4 | 4th Semester | 16 | 100 |
| **Total** | | **68** | **2000** |

**NB:**

* **Any one of the Courses in Appendix-I is to be Decided by the Concerned Department for Audit-1 (1st Sem)**
* **Any one of the Courses in Appendix-II is to be Decided by the Concerned Department for Audit-2 (2nd Sem)**
* **Any one of the Courses in Appendix-III is to be Decided by the Concerned Department for Open Elective (3rd Sem)**

**Semester-1**

**Core 1: Power Electronic Converters (PPCEE103)**

**COURSE OBJECTIVES:**

1. Understand the operation of different Phase controlled rectifier topologies.
2. Understand the concepts and basic operation of SPWM inverters.
3. Understand different switch mode topologies of DC-DC converters.

**Module I:**

**Power devices:** Switching characteristics and gate driver of Power BJT, IGBT and Power Mosfet

**Phase controlled rectifiers**– Single phase half wave and full wave controlled rectifier with R, R-L and R-L-E Loads. Single phase half controlled bridge rectifier-Input line current harmonics and power factor-Inverter mode of operation of full converter.

Three phase half wave controlled rectifier with R,R-L an R-L-E loads. Three phase semi and full converters with RL and RLE loads. Input side current harmonics and power factor. *Dual Converters-Circulating current mode and Non circulating current mode operation*

**Module-II**

**Switch-mode dc-ac inverters**. Basic concepts, SinPWM in single phase full bridge voltage source inverters, Unipolar and Bipolar switching , DC side current, Ripple in the inverter output, Spectral content in the output.

Three phase SPWM inverters, Voltage control and harmonic minimization in inverters, Effect of blanking time on inverter output voltage, DC side current, Ripple in the inverter output, Spectral content in the output.

**Module III**

**DC-DC Converters:**Buck, Boost, Buck-Boost and CukSMPS Topologies. Basic Operation- Waveforms - modes of operation – Output voltage ripple, linear power supplies

Push-Pull and Forward Converter Topologies - Basic Operation. Waveforms - Voltage Mode Control. Flyback Converter Topology- discontinuous mode operation-waveforms .and Control - Continuous Mode Operation-Waveforms and control

**AC voltage regulators**-Types of ac voltage regulators-single phase full wave ac voltage controllers. Three phase ac voltage regulators.3-Phase cycloconverter

**Text:**

*1. Ned Mohan et. al : Power Electronics ,John Wiley and Sons*

*2. B K Bose : Modern Power Electronics and AC Drives, Pearson Edn (Asia)*

*3. M.H Rashid: Power Electronics, Pearson*

**References:**

*1. G K Dubey et. al :Thyristorised Power Controllers , Wiley Eastern Ltd.*

*2. P C Sen : Power Electronics , TMH*

**COURSE OUTCOMES:**

Students will be able to

1. Understand and Analyze Power Electronic Converters.
2. Design the switching scheme of SPWM inverters.
3. Acquire the knowledge of controlling DC-DC converters.

**Core 2: Electric Drives (PPCEE104)**

**COURSE OBJECTIVES:**

The students should be able to

1. Understand the basic electrical drive system and its practical applications
2. Model and control the dc and ac drive systems
3. Design of converters for drive system
4. Understand scalar control of electrical drives

**Module-I**

**Introduction to motor drives:** Components of power electronic Drives- Criteria for selection of Drive components, Dynamics of Electrical Drives-Fundamentals of Torque Equations. Multiquadrant operations, Components of Load Torques, Classification of load torques, Steady state stability, Closed loop control of drives

**Module- II**

**Converters and Chopper fed DC Motor Drives:** Modelling of dc machines, Steady state characteristics with armature and field control (separately excited, shunt and series), Phase controlled converter fed D C Motor Drives- Steady state analysis of the 1-phase and 3-phase full converter controlled DC motors Drive, Drive Transfer functions, two quadrant dc motor drive with field weakening. Four quadrant dc motor drive.

Chopper- Controlled DC motor drive: Model of the chopper fed separately excited dc motor drives, Steady state analysis of chopper- controlled dc motor drives–continuous and discontinuous conduction operation, DC motor Drive with field weakening, four quadrant DC motor drives, Transfer Functions, closed-loop operation.

**Module-III**

**Induction motor drives:** Torque speed characteristics of 3-phase induction motor drive, effect of supply voltage unbalance and harmonics on induction motor operation, braking of induction motor speed control of 3-phase induction motor by varying stator frequency and voltage – variable frequency PWM-VSI drives-variable frequency CSI drives-comparison of variable frequency drives- Line frequency variable stator voltage drives- soft start of induction motors-Dynamic and regenerative braking of variable frequency induction motor drives, speed reversal operation – speed control by static slip power recovery, static Kramer and Scherbius drives.

Traction Motors: Starting, Speed-Time characteristics of locomotives, Braking, Traction Motors used in practice, Converters for traction applications

Industrial Drives-Digital control of electric drives, Stepper Motor Drives, Servo Motor Drives and Applications

**Text Books:**

1. Bimal.K. Bose, “Power Electronics and Variable frequency drives”, Standard Publishers Distributors, New Delhi, 2000
2. M. H. Rashid, "Power Electronics - Circuits, Devices and Applications", P.H.I Private Ltd. New Delhi, Second Edition, 1994
3. Bimal K Bose, “Modern Power Electronics and AC Drives” PHI
4. R. Krishnan, “Electric motor drives: modeling, analysis and control, Prentice-Hall, India.
5. G.K Dubey. “Fundamentals of Electric Drives”, Narosa Publishing House.
6. P.C. Sen,*Thyristor DC Drives*,Wiley-Interscience Pub., Digitized on Dec, 2006.

**COURSE OUTCOMES:**

The students will be able to

1. Understand and analyse drive systems
2. Learn design of controllers for electrical drive systems
3. Design modulation strategies of Power Electronic Converters for drive applications.

**MAPPING OF CO’S WITH PO’S**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **PO-1** | **PO-2** | **PO-3** | **PO-4** | **PO-5** | **PO-6** | **PO-7** | **PO-8** |
| **CO-1** |  | X | X |  |  |  | X | X |
| **CO-2** | X | X |  | X | X | X | X |  |
| **CO-3** | X | X | X | X | X | X | X | X |

**PE 1: Solar Photovoltaic Systems (PPEEE103)**

**COURSE OBJECTIVES:**

1. To understand the fundamentals of a solar cell
2. To analyze different techniques for maximum power extraction from the PV system
3. To gain knowledge of different PV based applications and their system design.

**MODULE I: SOLAR CELL FUNDAMENTALS**

Photovoltaic effect: Principle of direct solar energy conversion into electricity in a solar cell. Solar cells, modules and arrays, fill factor, efficiency

Solar PV modules: series and parallel connection of cells, mismatch in cell/module, mismatch series and parallel connections, commercial solar cells

PV Modelling: Equivalent circuit of PV cell, output characteristics, Double and single diode models, from data sheet values to model parameters, PV module equivalent parameters, effect of solar irradiance, effect of temperature on PV module power output.

**MODULE II: CONTROL OF PV SYSTEM**

Maximum Power Tracking: dynamic optimization problem, Fractional open circuit voltage and short circuit current, incremental conductance algorithm, Perturb and observe approach, improvements of P&O MPPT algorithm, MPPT for rapidly changing irradiance conditions,

Power converters and control for PV system: Design of dc/dc converter, single phase and three-phase inverter with PV as a source.

Grid Synchronization: Grid support features of utility-scale PV with storage, Micro-grids, and frequency/voltage control in islanded mode of operation, Demand response, distributed storage and smart grid concepts.

PV inverter structures: Three phase PV inverters,

Response to Abnormal Grid Conditions: Fault Voltage deviations, Frequency deviations, Reconnection after trip.

**MODULE III: APPLICATION AND DESIGN OF PV SYSTEMS**

Stand-alone PV system, Grid Interactive PV System, Hybrid solar PV system.

System components - PV arrays, inverters, batteries, charge controls, net power meters

Building-integrated photovoltaic units, grid-interacting central power stations, standalone devices for distributed power supply in remote and rural areas, solar cars, aircraft, space solar power satellites.

Design of solar PV systems and cost estimation. Stand-alone PV system, Home lighting and other appliances, solar water pumping systems.

**Text Books:**

1. Chetan Singh Solanki., Solar Photovoltaic: “Fundamentals, Technologies and Application”, PHI Learning Pvt., Ltd., 2009.
2. Jha .A.R, “Solar Cell Technology and Applications”, CRC Press, 2010.
3. Nicola Femia, Giovanni Petrone, Giovanni Spagnuolo, Massimo Vitelli, Power Electronics and control for maximum Energy Harvesting in Photovoltaic Systems,CRC Press,2013.
4. Remus Teodorescu, Marco Liserre, Pedro Rodriguez, Grid Converters for Photovoltaic and Wind Power Systems, John Wiley and Sons, Ltd., 2011.

**Reference Books**

1. John R. Balfour, Michael L. Shaw, Sharlave Jarosek., “Introduction to Photovoltaics”, Jones & Bartlett Publishers, Burlington, 2011.
2. Luque.A. L and Andreev. V.M, “Concentrator Photovoltaic”, Springer, 2007.
3. Partain. L.D, Fraas L.M., “Solar Cells and Their Applications”, 2nd ed., Wiley, 2010.
4. Sukhatme. S.P, Nayak. J.K, “Solar Energy”, Tata McGraw Hill Education Private Limited, New Delhi, 2010.
5. Sudipta Chakraborty, Marcelo G. Simões, and William E. Kramer. Power Electronics for Renewable and Distributed Energy Systems: A Sourcebook of Topologies, Control and Integration. Springer Science & Business, 2013.

**COURSE OUTCOMES:**

Students completing this course will be able to:

**CO 1**: Understand the principle of direct solar energy conversion to electric power using PV technology.

**CO 2:** Design and analyze the issues related to Grid integrated solar PV systems

**CO 3:** Understand the working principle of Grid tied solar PV system with and without storage systems.

**CO4**: Evaluate economies and ecology of a PV system

**PE 1: Storage Technology (PPEEE104)**

**COURSE OBJECTIVES:**

1. To gain knowledge about the need of different energy storage techniques and their industrial applications in the current energy scenario.
2. To analyze different emerging technologies in energy storage.
3. To design storage technologies in hybrid systems and electric vehicles.

**Syllabus:**

**Module I- Introduction to energy storage technology and energy storage processes**

The need for energy storage - Types and general concepts

Energy storage processes:

·       Electrical energy storage – Super capacitors: Fundamentals and types of super capacitors

·       Magnetic Energy Storage – superconducting systems,

·       Thermal Energy Storage – phase change materials,

·       Mechanical - Pumped hydro, Flywheels and Compressed air energy storage,

·       Chemical - Hydrogen Storage, Production and storage alternatives, Other approaches to hydrogen storage.

**Module II- Electrochemical energy storage**

Thermodynamics, Kinetics and electrochemistry of battery Systems Primary, secondary and Flow batteries.

**Module III– System design & Applications**

* + - Energy storage for renewable energy sources - Battery sizing and stand-alone Applications
    - Large scale applications/ Stationary (Grid applications) – Power and energy applications
    - Small scale applications - Portable storage systems/medical devices
    - Mobile storage applications
      * Electric vehicles - Introduction and types of EV’s
      * Batteries and fuel cells – future technologies
    - Hybrid systems for energy storage

**Books and References:**

* 1. Energy Storage - Technologies and Applications, *Ed: Ahmed Faheem Zobaa, ISBN* *978-953-51-0951-8, 328 pages, Publisher: InTech, 2013.*
  2. J. Jensen and B. Sorenson. *Fundamentals of Energy Storage.* Wiley-Interscience, New York(1984)
  3. Handbook of battery materials, Ed: C. Daniel, J. O. Besenhard, *2nd Edition, Wiley- VCH Verlag GmbH & Co. KgaA, 2011.*
  4. Electric & Hybrid Vehicles, G. Pistoia, *Elsevier B.V, 2010*.

**COURSE OUTCOMES:**

**CO1:** Understand various storage technologies.

**CO2:** Able to analyze the reliability, technical efficiency and economic efficiency of an integrated system.

**CO3**: Exposure to modern innovative technologies applied for energy storage in fuel cell, hydrogen storage, electromagnetic storage etc.

**CO4**: Design of battery in electric vehicles and hybrid systems

**PE 2: FACTS and Custom Power Devices (PPEEE105)**

**COURSE OBJECTIVES:**

1. To impart knowledge on flexible AC transmission system criteria, advantages, and control parameters.
2. To impart knowledge on various compensation techniques for control of FACTs devices.
3. To impart knowledge on various practices being followed in the real system scenario.

**Syllabus:**

**Module 1:**

**Flexible AC Transmission System:** Transmission inter connections, flow of power in ac systems, loading capability, dynamic stability considerations, basic types of FACTS controllers.

**Module 2:**

**Static Shunt and Series Compensators:** Objectives of shunt compensation, Static VAR compensators (SVCs), STATCOM configuration, Characteristics and control, Comparison between STATCOM and SVC. Objectives of series compensation, Variable Impedance type series compensators, switching converter type series compensators, external control for series reactive compensators.

**Module 3:**

**Power Flow Control Techniques:** Principle of operation and characteristics, independent active and reactive power flow control, comparison of UPFC with the series compensators and phase angle regulators, Principle of operation, characteristics and control aspects of IPFC.

**Module 4:**

**Custom Power Devices:** Introduction to custom power devices, DSTATCOM and DVR operating principles, Applications of DSTATCOM and DVRs in Distribution Systems.

**Suggested Books:**

1. Hingorani ,L.Gyugyi, ‘ Concepts and Technology of Flexible AC transmission system’, IEEE Press New York, 2000.
2. K.R.Padiyar, “FACTS controllers in power transmission and distribution”, New Age International Publishers, Delhi, 2007.

**COURSE OUTCOMES (CO’S)**

At the end of the course, the students will be able to

1. gain knowledge on flexible AC transmission system criteria, advantages, and control parameters.
2. gain knowledge on various compensation techniques for control of FACTs devices.
3. gain knowledge on various practices being followed in the real system scenario.

**PE 2: Advanced Control Systems (PPEEE106)**

**Objectives of the course**

|  |  |
| --- | --- |
| OB1 | To provide a concept on Advanced Control system analysis and design techniques using state variable method for Continuous-Time and Discrete-Time Systems |
| OB2 | To analyse the behaviour of nonlinear control and adaptive control systems |

***Module 1 Discrete-Time Systems***

State Space Representations of Discrete Time Systems, Solution of Discrete Time State Equations, Discretization of Continuous Time State Equations, Digital PID Controller Controllability, Observability, Pole Placement by State feedback, Deadbeat response

***Module 2: Optimal Control***

***(Continuous-Time and Discrete-Time Systems)***

Performance Indices, Quadratic Optimal Regulator / Control Problems, Formulation of Algebraic Riccati Equation (ARE) for continuous and discrete time systems. Solution of Quadratic Optimal Control Problem using Lagrange Multiplies for continuous and discrete-time Systems, Evaluation of the minimum performance Index, Optimal Observer, The Linear Quadratic Gaussian (LQG) Problem, Pole Placement by State feedback using Optimal feedback Gain for Quadratic Regulator and LQG problem, Introduction to H∞ Control.

***Module 3: Nonlinear and Adaptive Control***

Stability: Basic concepts, Stability definitions and theorems, Lyapunov functions for LTI systems, Fractional Differentiation and its application

Model Reference Adaptive Control (using MIT Rule and Lyapunov Theory), Recursive Least Square Estimation, stochastic Self-Tuning Control (Minimum Variance and Pole-placement Control), Sliding Mode Control, Sliding mode control algorithms

**Text Books**

1. M. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill, 3rd Edition, 2009
2. J. J. E. Slotine and W. Li, Applied Nonlinear Control, Prentice Hall, 1991.
3. D. S. Naidu, Optimal Control Systems, CRC Press, 2002.
4. K.J. Astrom and B. Wittenmark, Adaptive Control, Pearson, 2006.
5. R. T. Stefani, B. Shahian, C.J. Savant, G.H. Hostetter, Design of Feedback Control Systems, OUP, 2002.

**Reference Books**

1. K.Ogata, Modern Control Engineering, Prentice-Hall of India, 5th Edition, 2010
2. K.Ogata, Discrete-Time Control System, 2nd edition (2001), Pearson Education Publication
3. H.K. Khallil, Non Linear Systems, 3rd edition (2002), Pearson Education
4. B. Friedland, *Control System Design - An Introduction to State-Space Methods*, McGraw-Hill, 2007
5. S.H. Zak, Systems and Control, Oxford Univ. Press, 2003

**COURSE OUTCOMES.**

On successful completion, students will have the ability to

**CO 1:** Analyse the stability of discrete system and nonlinear system

**CO 2:** Design compensators using classical techniques and Optimal Control Law

**CO 3:** Analyse both linear and nonlinear system using state space methods

**CO 4:** Understand the concept and implementation of Adaptive Control

**MAPPING OF CO’S WITH PO’S**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **PO-1** | **PO-2** | **PO-3** | **PO-4** | **PO-5** | **PO-6** | **PO-7** | **PO-8** |
| **CO-1** | High | High | High | Medium | High | Medium | Medium | Low |
| **CO-2** | High | High | High | Medium | High | Medium | Medium | Low |
| **CO-3** | High | High | High | Medium | High | Medium | High | Low |
| **CO-4** | High | High | High | Medium | High | Medium | High | Low |

**MC: Research Methodology & IPR (PMCMH101)**

**Module I: (10 Hours)**

Introduction to RM: Meaning and significance of research. Importance of scientific research in decision making. Types of research and research process. Identification of research problem and formulation of hypothesis. Research Designs.

Types of Data: Primary data Secondary data, Design of questionnaire; Sampling fundamentals ad sample designs, Methods of data collection, Measurements and Scaling Techniques, Validity & Reliability Test.

**Module II: (10 Hours)**

Data Processing and Data Analysis-I, Data editing, Coding, Classification and Tabulation, Descriptive and Inferential Analysis, Hypothesis Testing- Parametric Test (z test, t test, F test) and non-parametric test (Chi square Test, sign test, Run test, Krushall-wallis test).

**Module III: (10 Hours)**

Data Analysis II: Multivariate Analysis- Factor Analysis, Multiple Regression Analysis. Discriminant Analysis, Use of Statistical Packages.

**Reference Books:**

1. Research Methodology, Chawla and Sondhi, Vikas

2. Research Methodology, Paneerselvam, PHI

**Course Outcomes:**

**CO1:** Understood the Meaning of research problem, Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem.

**CO2:** Got the knowledge of How to get new ideas (Criticizing a paper) through the Literature Survey (i.e. Gap Analysis).

**CO3:** Understood the Filing patent applications- processes, Patent Search, Various tools of IPR, Copyright, Trademarks.

**CO4:** Understood How to apply for Research grants and Significance of Report Writing, Steps in Report Writing, Mechanics and Precautions of Report Writing, Layout of Research Report.

**CO5:** Got the knowledge of How to write scientific paper & Research Proposal - Structure of a conference and journal paper, how (and How Not) to write a Good Systems Paper:

**Lab 1: Power Electronics Lab (PLCEE102)**

**COURSE OBJECTIVES:**

Students should be able to

1. Understand the working of Controlled rectifiers, Choppers and AC Regulators
2. Understand multi quadrant operation of a Dual Converter.
3. Understand the different PWM schemes of inverters.

|  |  |
| --- | --- |
| Sl. No | Experiments |
| 1 | To Study single-phase (i) fully controlled (ii) Half controlled bridge rectifiers with resistive and inductive loads |
| 2 | To Study three-phase (i) fully controlled (ii) Half controlled bridge rectifiers with resistive and inductive loads. |
| 3 | To study operation of IGBT/MOSFET based Buck chopper |
| 4 | To study operation Dual Converter with resistive and inductive loads. |
| 5 | To Study single-phase AC voltage regulator with resistive and inductive loads |
| 6 | To Study Three-phase AC voltage regulator with resistive and inductive loads |
| 7 | To Study various pwm based single-phase bridge inverter |
| 8 | To Study pwm based three-phase bridge inverter |
| 9 | Calculation of input power factor and displacement factor for single phase rectifier circuit |
| 10 | Development of firing angle table for +ve, -ve and zero sequence voltage for 3-ph inverter circuits |
| 11 | Performance calculation of various rectifier circuits |

**COURSE OUTCOMES:**

Students will be able to

1. Understand and Analyze the performance parameters of converters.
2. Analyze Spectral content for Various PWM schemes.
3. Design the firing circuits employed for Power Electronic Converters.

**Lab 2: Power Electronics Simulation Lab (PLCEE103)**

**COURSE OBJECTIVES:**

Students should be able to

1. Simulate Controlled rectifiers and AC Regulators using MATLAB/PSIM.
2. Design switching schemes of switch mode DC-DC converters in MATLAB/PSIM.
3. Design different PWM schemes of inverters in MATLAB/PSIM

|  |  |
| --- | --- |
| Sl. No | Experiments |
| 1 | To Study single-phase (i) fully controlled (ii) Half controlled bridge rectifiers with R, R-L, R-L-E loads using MATLAB/PSIM software |
| 2 | To Study three-phase (i) fully controlled (ii) Half controlled bridge rectifiers with R, R-L, R-L-E loads using MATLAB/PSIM software |
| 3 | To study Buck, Boost Regulator using MATLAB/PSIM software. |
| 4 | To study forward and flyback converter using MATLAB/PSIM software |
| 5 | To Study Dual converter with resistive and inductive loads using MATLAB/PSIM software |
| 6 | To Study Three-phase AC voltage regulator with resistive and inductive loads using MATLAB/PSIM software |
| 7 | To Study sinusoidal pwm based single-phase bridge inverter using MATLAB/PSIM software |
| 8 | To Study pwm based three-phase bridge inverter using MATLAB/PSIM software |

**COURSE OUTCOMES:**

Students will be able to

1. Analyze the performance of converters in MATLAB/PSIM platform.
2. Control the switch mode regulators in MATLAB/PSIM platform.
3. Analyze Harmonic content of PWM based inverters in MATLAB/PSIM platform.

**Audit-1**

**[To be decided by the Department]: Refer Appendix-I**

**Semester-2**

**Core 3: Advanced Power Electronic Converters (PPCEE203)**

**COURSE OBJECTIVES:**

Students should be able to

1. Understand the operation of Switch mode Rectifiers and Multi-Level Inverters
2. Understand the concepts of different PWM techniques.
3. Understand different Resonant Converter topologies.

**Syllabus:**

**Module I:**

Switched Mode Rectifier *-* Operation of Single/Three Phase Bridges in Rectifier Mode. Control Principles. Control of the DC Side Voltage. Voltage Control Loop. The inner Current Control Loop.

Introduction to active power factor control.

**Module II**

Multi-Level Inverters of Diode Clamped Type, Flying Capacitor Type and Cascaded type; Basic Topology and Waveforms, Improvement in harmonics, suitable modulation strategies -Space Vector Modulation – Sigma-Delta Modulation, Minimum ripple current PWM method. Current Regulated Inverte*r -*Current Regulated PWM Voltage Source Inverters.

*Methods of Current Control. Hysteresis Control. Variable Band Hysteresis Control. Fixed Switching Frequency Current Control Methods.*

**Module III**

Introduction to Resonant Converters. Classification of Resonant Converters.Basic Resonant Circuit Concepts. Zero Voltage Switching Clamped Voltage Topologies. Resonant DC Link Inverters with Zero Voltage Switching, zero current switching resonant inverter.

Introduction to matrix converter and Z-source inverter: Principle and control strategy

**Text:**

*1. Ned Mohan et. al : Power Electronics ,John Wiley and Sons*

*2. B K Bose : Modern Power Electronics and AC Drives, Pearson Edn (Asia)*

*3. M.H Rashid: Power Electronics, Pearson*

*4. M.H Rashid: Digital Simulation of Power Electronics, Pearson*

**References:**

*1. G K Dubey et. al :Thyristorised Power Controllers , Wiley Eastern Ltd.*

*2. P C Sen : Power Electronics , TMH*

**COURSE OUTCOMES:**

At the end of the course, the students will be able to

1. Understand and Analyze Advanced Power Electronic Converters like Multi level

inverters, Matrix Converter and Z-source Inverter

1. Design different modulation strategies of Power Electronic Converters.
2. Simulate Power Electronic Systems and analyze the system Response.

**Core 4: Modeling, Analysis & Control of Electric Drives (PPCEE204)**

**COURSE OBJECTIVES:**

The students should be able to

1. Understand the modeling of Induction and Synchronous machines in various reference frames
2. Understand the principle of vector control and analyse the drive systems
3. Understand and analyse various speed sensor- less vector control schemes applied to Induction and Synchronous machines

**Module I**

Dynamic Modeling of Induction and Synchronous Machines: abc and dq modeling, Stator Reference, Rotor Reference and Synchronously Rotating Reference Frame Models.

**Module II**

Control of Induction Motor (IM) Drive- Principle of vector control, Direct vector control and Indirect vector control schemes, Flux weakening operation, Direct rotor-flux oriented control of IM, Indirect rotor-flux oriented control of IM, Speed controller design for an Indirect Vector Controlled Induction Motor Drive, Air-gap flux and Stator-flux oriented vector control schemes of Induction Motor, Flux observers, Speed sensor-less control, Direct torque and flux control of induction motor.

**Module III**

Open-loop control of synchronous motor, Self-controlled synchronous motor, CSI fed synchronous motor drive, steady state phasor diagram of salient pole synchronous motor, angle control and vector control of synchronous motor, dynamic equations, Cycloconverter fed wound field synchronous motor drives

Control of Surface Permanent Magnet Machine and interior permanent magnet machine, Vector Control of Permanent magnet synchronous motor (PMSM), Brushless dc Motor (BLDCM) drives, Switched Reluctance Motor Drives, Synchronous Reluctance Motor Drives

**Essential Reading:**

Texts: -

1. R. Krishnan, “Electric Motor Drives: Modeling, Analysis and Control”, Prentice Hall.
2. P. S. Bhimbra, “Generalized Theory of Electric Machines”, Khanna Publication.
3. B. K. Bose, “Modern Power Electronics and AC Drives”, Pearson Education.
4. G. K. Dubey, Power Semiconductor Controlled Drives, Prentice-Hall International, 1989.
5. P. C. Krause, O.Wasynczuk and S.D.Sudhoff, “Analysis of Electric Machinery and Drive Systems” Willy IEEE press 3rd edition

**Supplementary Reading:**

1. G. K. Dubey, *Fundamentals of Electrical Drives*, Narosa Publishing House, 2002.

2. W. Leonhard, *Control of Electrical drives*, Springer-Verlag, 1985.

**COURSE OUTCOMES:**

At the end of the course, the students will be able to

1. Model and analyse various direct and indirect vector control schemes applied to

Induction motor

1. Design the sensor less vector control of Induction and Synchronous with simulation
2. Analyse and simulate special types of drive machines such as Switched Reluctance motor

and Synchronous Reluctance motors etc.

**PE 3: Artificial Intelligence and Machine Learning (PPEEE202)**

**COURSE OBJECTIVES:**

1. To learn about biological foundations of Intelligent Systems
2. To learn about Artificial Neural Network
3. To learn about Fuzzy Logic
4. To know about GA and other Evolutionary Algorithms

**Module 1**

**Artificial Neural Networks and Deep Learning**

Neural Network representations, appropriate problems for neural network learning

Supervised Learning: Perceptrons, representational power of perceptrons, perceptron training rule, Gradient Descent and Delta rule, Multilayer perceptron and backpropagation algorithm, Linear Regression: Linear regression and prediction of continuous data values, Recurrent Neural Networks, RBFN

Unsupervised Learning: Competitive Learning, K-Means clustering, Hierarchical Clustering

Support Vector machines: Classification of data points using support vectors

**Module 2**

**Fuzzy Inference Systems:**

Basic Concepts of Fuzzy Logic, Fuzzy vs Crisp Set, Linguistic variables, Membership Functions, Operations of Fuzzy Sets, Fuzzy If-Then Rules, Variable Inference Techniques, Defuzzification, Basic Fuzzy Inference Algorithm,

Fuzzy Neural Network

System Identification using Fuzzy and Neural Networks

**Module 3:**

**Genetic Algorithm:**

Representing Hypothesis, Genetic operators, Population Evolution, Genetic programming,

Introduction to other evolutionary Algorithms like PSO, BFO etc

**Text Books**

1. Tom M Mitchell, Machine Learning, PHI LEARNING PVT. LTD-NEW DELHI, 2015
2. Ethem Alpaydin, Introduction to Machine Learning, The MIT Press, 3rd Edition, 2015
3. Simon Haykins, Neural Networks, Prentice Hall
4. Timothy Ross, Fuzzy Logic with Engineering Application- McGraw Hill Publishers

**Reference Books**

1. R. Duda, P. Hart, and D. Stork. "Pattern Classification", 2nd edition, Wiley Interscience, 2001.
2. C. M. Bishop. "Neural Networks for Pattern Recognition", Oxford University Press, 1995.
3. T. Hastie, R. Tibshirani and J. Friedman, "Elements of Statistical Learning: Data Mining, Inference and Prediction". Springer-Verlag, 2001.
4. T. Cover and J. Thomas. "Elements of Information theory", Wiley Interscience, 1991.
5. Golding, “Genetic Algorithms”, Addison Wesley
6. Junhong NIE & Derek Linkers, “Fuzzy Neural Control”, PHI

**COURSE OUTCOME.**

On successful completion, students will have the ability to

1. Apply the concepts of Neural network for pattern recognition andclassification
2. Apply Fuzzy logic principles to take decisions and design controllers
3. Apply GA principles for solving optimization problems

**PE 3: Programmable Embedded Systems (PPEEE203)**

**COURSE OBJECTIVE:**

1. Discuss the major components, architecture, communication, interfacing etc. for an embedded system
2. Implement small programs to solve well-defined problems on an embedded platform
3. Develop familiarity with tools used to develop in an embedded environment

**Syllabus**

Module -1 (14 Hours)

Introduction to Embedded Systems; The AVR Microcontroller: AVR Architecture and Assembly Language Programming, Branch, Call and Time delay Loop, AVR I/O Port Programming, Arithmetic, Logic Instructions, and Programs, ADC, DAC and Sensor Interfacing (7 Hours)

Interrupts, DMA, Timers, Serial Communication (RS 232), USB, CAN, I2C Protocol, SPI Protocol and Interfacing (7 Hours)

Module -2 (10 Hours)

ARM: ARM Architecture and Assembly Language Programming, Arithmetic and Logic Instructions and Programs, Branch, Call, and Looping in ARM, Signed Numbers and IEEE 754 Floating Point, ARM Memory Map, Memory Access, and Stack

Introduction to Operating Systems, Real Time Operating Systems

Module -3 (6 Hours)

Basics of Wireless communication, Wi-Fi and the IEEE 802.11 Wireless Lan Standard: protocol architecture, IEEE Architecture and Services

Text Books:

1. “AVR Microcontroller and Embedded Systems Using Assembly and C” by Muhammad Ali Mazidi, SarmadNaimi, SepehrNaimi, Pearson New International Edition, 2011
2. “ARM Assembly Language Fundamentals and Techniques”, by William Hohl, Christopher Hinds, CRC Press, 2nd Edition, 2014
3. “ARM Assembly Language Programming & Architecture”: by Muhammad Ali Mazidi, SarmadNaimi, SepehrNaimi, Janice Mazidi, 2013
4. “Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud” by William Stallings, Pearson New International Edition, 2016
5. “Wireless Communications and Networks” by William Stallings, Pearson New International Edition, 2nd Edition, 2005
6. “Embedded System Design”, by Marwedel, Peter, Springer, 2011
7. AVR Manuals
8. Assembly Language Coding Manual.

**COURSE OUTCOME:**

**CO 1:** Understand the basic functions and structure of embedded system

**CO 2:** Become aware of concepts of embedded systems like IO, timers, interrupts, interaction with peripheral devices

**CO 3:** Become familiar with programming environment used to develop embedded systems

**CO 4:** Design real time embedded systems using the concept of RTOS

**CO 5:** Become familiar with design of embedded systems in IoT environment

**PE 4: Smart Grid Technology (PPEEE206)**

**COURSE OBJECTIVES**

1. To Study about Smart Grid technologies, different smart meters and advanced metering infrastructure.
2. To familiarize with the power quality management issues in Smart Grid.
3. To familiarize with the high performance computing for Smart Grid applications

**Syllabus:**

**Module-I:**

Evolution of Electric Power Grid, introduction to smart Grid, Concept, definitions, architecture and functions of Smart Grid. Need of Smart Grid. Difference between conventional & smart grid. Opportunities & Challenges of Smart Grid,

Introduction to Smart Meters, Real Time Pricing, Smart Appliances. Automatic Meter Reading(AMR). Outage Management System(OMS). Home & Building Automation, Substation Automation, Feeder Automation, Smart Sensors, Geographic Information System(GIS). Intelligent Electronic Devices(IED) & their application for Monitoring & Protection.

**Module-II:**

Phasor Measurement Units (PMU), Wide Area Measurement System(WAMS), Wide-Area based Protection and Control

Micro-grid concepts, need and application, Issues of Interconnection. Protection & control systems for micro-grid.

Storage systems including Battery, SMES, Pumped Hydro. Compressed Air Energy Storage.

**Module-III:**

Variable speed wind generators, fuel-cells, micro-turbines. Integration of renewables and issues involved, Advantages and disadvantages of Distributed Generation.

Power Quality & EMC in smart Grid. Power Quality issues of Grid connected Renewable Energy Sources. Power Quality Conditioners for micro-grid. Web based Power Quality monitoring, Power Quality Audit

**COURSE OUTCOMES:**

After successfully completing this course a student will able to:

**CO 1:** Understand the fundamental element of the smart grid

**CO 2:** Explain various communication, networking, and sensing technologies involved in smart grid

**CO 3:** Explain various integration aspects of conventional and non-conventional energy sources.

**CO 4:** Explain distributed generation coordination including monitoring of smart grid using modern communication infrastructure

**CO 5:** Analyze Micro-grid as a hybrid power system with advantages and challenges in future.

**CO 6:** Be able to apply this knowledge in analysis and problem solving of smart grid architectures needs and challenges

**Suggested Books:**

1. Ali Keyhani, “Design of Smart power grid renewable energy systems”, Wiley IEEE,2011.
2. Clark W. Gellings, “The Smart Grid: Enabling Energy Efficiency and Demand Response”, CRC Press, 2009.
3. Stuart Borlase, “Smart Grid: Infrastructure, Technology and solutions “CRC Press.
4. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, “Smart Grid: Technology and Applications”, Wiley.
5. Andres Carvallo, John Cooper, “The Advanced Smart Grid: Edge Power Driving Sustainability: 1”, Artech House Publishers July 2011
6. MladenKezunovic, Mark G. Adamiak, Alexander P. Apostolov, Jeffrey George Gilbert “Substation Automation (Power Electronics and Power Systems)”, Springer

**PE 4: Power Quality (PPEEE208)**

**COURSE OBJECTIVES:**

1. To impart knowledge on issues of power quality and factors governing it.
2. To impart knowledge on impacts of poor power quality on the system and the consumers.
3. To impart knowledge on harmonics (cause, effect and compensating techniques).

**Syllabus:**

**Module 1:**

**Electric Power Quality Phenomena:** Impacts of power quality problems on end users, Power quality standards, power quality monitoring.

**Power Quality Disturbances:** Transients, short duration voltage variations,long duration voltage variations, voltage imbalance, wave-form distortions, voltage fluctuations, power frequency variations, power acceptability curves.

**Module 2:**

**Power Quality Problems in Power Systems:** Poor load power factor, loads containing harmonics, notching in load voltage, dc offset in loads, unbalanced loads, disturbances in supply voltage.

**Transients:** Origin and classification- capacitor switching transient-lighting-load switching-impact on users, Protection and mitigation of transients.

**Harmonics:** Harmonic distortion standards, power system quantities under non sinusoidal conditions-harmonic indices-source of harmonics-system response characteristics-effects of harmonic distortion on power system apparatus –principles for controlling harmonics, reducing harmonic currents in loads, filtering, modifying the system frequency response- Devices for controlling harmonic distortion, inline reactors or chokes, zigzag transformers, passive filters, active filters.

**Module 3:**

**Power Quality Conditioners:** Shunt and series compensators, Distribution STATCOMS (DSTATCOMS) and Dynamic Voltage Restorers (DVRs), Rectifier supported DVR, DC Capacitor supported DVR, DVR Structure, Voltage Restoration – Series Active Filter – Unified power quality conditioners.

**Suggested Books:**

Ghosh Arindam and Ledwich Gerard, ‘Power quality enhancement using custom power devices’ Springer.

Arrillaga J., Watson N. R. and Chen S., ‘Power System Quality Assessment’ Wiley.

Caramia P, Carpinelli G and Verde P, ‘Power quality indices in liberalized markets’ – Wiley

Angelo Baggini ‘Handbook of Power Quality’ – Wiley.

G.T.Heydt, “Electric Power Quality”, Stars in a Circle Publications, 1994(2nd edition)

R.C. Duggan, ‘Power Quality’, TMH Publication, 2002

**COURSE OUTCOMES (CO’S)**

At the end of the course, students will be able to:

1. gain knowledge on issues of power quality and factors governing it.
2. gain knowledge on impacts of poor power quality on the system and the consumers.
3. gain knowledge on harmonics (cause, effect and compensating techniques).

**Mini Project with Seminar (PPREE201)**

**[To be decided by the Department]**

**Lab 3: Electrical Drives Lab (PLCEE203)**

**COURSE OBJECTIVES:**

The students should be able to

1. Understand the scalar control techniques of dc and ac motors using staticconverters
2. Simulate the dc and ac drive systems using MATLAB/PSIM
3. Design of various converters for dc and ac drive systems

|  |  |
| --- | --- |
| Sl. No | Experiments |
| 1 | Study of Thyristor controlled DC Drive |
| 2 | Study of AC single phase motor speed control using AC voltage controller |
| 3 | Study of V/f control operation of three phase induction motor |
| 4 | Study of static rotor resistance control of 3 phase induction motor |
| 5 | Regenerative/Dynamic Braking operation of DC motor drive using MATLAB/PSIM software. |
| 6 | PWM inverter fed three phase induction motor control using MATLAB/PSIM software. |
| 7 | Study of chopper fed DC motor drive using MATLAB/PSIM software. |
| 8 | Regenerative/Dynamic Braking operation of AC motor drive using MATLAB/PSIM software. |

**COURSE OUTCOMES:**

At the end of the course, the students will be able to

1. analyse braking operation of dc and ac drives in MATLAB/PSIM platform
2. control various converters for dc and ac drives
3. analyse ac voltage controller for ac motor speed control

**Lab 4: Embedded Systems Lab (PLCEE204)**

**Course Objective:**

1. Analyze and design of Embedded systems for engineering applications
2. Understanding the programming language for various Embedded platforms
3. To be aware of challenges and scopes of algorithm implementation

Programming using 8-bit MCU (AVR) (ATMega32/ ATMega128)

1. Square wave generation using 8-bit MCU (blinking of LED)
2. DAC interfacing and generation of ramp wave.
3. Transfer data from ADC and then send the output to the DAC (Study of sampling Time)
4. Implementation of simple Moving Average Filter (Digital Low pass Filter)
5. Revise and report submission on implementation of Digital FIR Filter

Programming using 32-bit MCU (ARM)

TI Launchpad (CC3200) / ARM programming introduction (2 sessions)

1. Implementation of Large order FIR filter.
2. Interfacing of Current Sensor (Hall Sensor) and display measurement of current on CRO

Android Programming

Session on Android Programming (How to build simple application)

1. Design of android application for interfacing ARM and wifi module with Android App.
2. Display of current measurement from ARM to Android App. (IoT)

**Course Outcome:**

1. An understanding of Assembly language programming for AVR
2. An ability to implement digital filter in 8-bit and 32-bit processor
3. An understanding of interfacing sensor and data acquisition for AVR and ARM
4. Being able to design small embedded systems application from functional

Requirements

**Audit-2**

**[To be decided by the Department]: Refer Appendix-II**

**Semester-3**

**PE 5: Grid Integration of Renewable Sources (PPEEE301)**

**COURSE OBJECTIVES:**

1. The main objective of the course is to provide students with the knowledge of the impacts caused by the integration of distributed renewable generation in the power system.
2. To provide student with the ability to use modern simulation tools to evaluate the performance of electric power systems with high penetration of renewable energy.

**MODULE-I**

Introduction to distributed generation/Micro Grid: General introduction to the concept of distributed generation, Standalone System, Integration of distributed renewable generation into the electricity system (Current status, challenges and prospects) and its impacts on the electrical system.

Network topologies with distributed generation: Description of the different network topologies where distributed renewable generation (Wind, Solar, Hydro, Tidal power) can be connected. Principles of design, operation.

**MODULE-II**

Power system Performance:

Impact of distributed generation on power system in terms of changes taking place and severity imposed, power quality issues, voltage quality issues, design of distributed generation.

Impact of distributed generation on power system in terms of overloading and losses, radial distribution networks, redundancy and meshed operation, losses, increasing the hosting capacity.

**MODULE-III**

Control of standalone system and Grid connected system (Voltage and frequency control). Phase Locked Loop, Islanding and reconnecting. Primary frequency control in large systems, Fault ride through.

Transmission system operation: Fundamental operation, Frequency control, Balancing and Reserves, Prediction of production and consumption, Restoration, Voltage stability, Angular stability.

**Textbooks:**

1. Bollen M.H.J., Hassan F., Integration of distributed generation in the power system. IEEE Press Series on Power Engineering. Wiley. Hoboken 2011.
2. Jenkins N., Allan R., Crossley P., Kirschen D., Strbac G., Embedded generation. IEE Power and Energy Series 31. London, 2000.
3. Jenkins N., Ekanayake J.B., Strbac G., Distributed generation. IET Renewable Energy Series 1. London 2010.
4. Keyhani A., Marwali M.N., Dai M., Integration of green and renewable energy in electric power systems. Wiley. Hoboken 2010.

**PE 5: Electric and Hybrid Vehicles (PPEEE304)**

**COURSE OBJECTIVE:**

1. Understand upcoming technology of hybrid system.
2. Understand different aspects of drives application
3. Learn the electric Traction

**Module-I**

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

**Module-II**

**Hybrid Electric Drive-trains**: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis.

**Electric Drive-trains:** Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis.

**Module-III**

**Electric Propulsion unit:** Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives

**Battery Management System(BMS)/Energy Management System (EMS):** Need of BMS, Converter control for power management, Software-based high level supervisory control, Mode of power transfer, Behavior of drive motor.

Fuel Cell based energy storage and its analysis

**Text Book:**

1. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003

**References:**

1. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.

2. MehrdadEhsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.

**COURSE OUTCOMES:**

After successfully completing this course a student will able to:

**CO 1:** Understanding of the operating principles of the electrical machines involved in hybrid cars.

**CO 2:** Understanding other power electronic circuits such as chargers and auxiliary drives used in vehicles.

**CO 3:** Choose the battery, traction motor and transmission appropriate for the power train of an EV or HEV.

**CO 4:** Analyze hybrid and electric vehicle power train systems to establish their optimal structure and calibration.

**PE 5: Modeling and Simulation (PPEEE303)**

COURSE OBJECTIVEs:

1. To provide a basic understanding of Probability Theory,
2. To provide a basic understanding of applied Linear Algebra and optimization problems, viz., their formulation, analytic and computational tools for their solutions,
3. To learn about applications of Linear Algebra and Probability Theory in modelling and simulation environment

Syllabus:

**Module 1:**

Probability and Random Process: Introduction, The Concept of a Random Variable, Functions of One Random Variable, Two Random Variables, Sequence of Random Variables, Statistics, Markov Chains

**Module 2:**

Linear Algebra: The geometry of linear equations, Elimination with matrices, Matrix operations and inverses, Vector spaces and subspaces, Orthogonality, Linear operators and matrix inverses: The LU factorization, The Cholesky factorization, Unitary matrices and the QR factorization, Projections and subspaces, Least squares approximations

**Module 3:**

Linear Algebra: Eigenvalues and eigenvectors, Linear dependence of eigenvectors, Diagonalization, Computation of eigenvalues and eigenvectors, Singular value decomposition: Matrix structure from the SVD, Pseudo-inverses and the SVD

Convex Optimization: Convex Sets, Convex Functions, Convex Optimization Problems, Unconstrained minimization, Equality Constrained Minimization

**Text Book:**

1. Probability, Random Variables and Stochastic Processes, by Papoulis and Unnikrishnan, Fourth Edition, 2002
2. Introduction to Linear Algebra, by Strang, Gilbert. 5th ed. Wellesley-Cambridge Press, 2016
3. Convex Optimization, by Stephen Boyd and Lieven Vandenberghe, Cambridge University Press, 2004

COURSE OUTCOMES:

1. Convert an Engineering statement problem into a precise mathematical probabilistic Statement
2. To understand matrix manipulations, vector space or subspace and orthogonal complement of a subspace
3. Use of various computational algorithms for unconstrained optimization, including steepest descent, Newton's method, conjugate-direction methods, and direct search methods

**Open Elective**

**[To be decided by the Department]: Refer Appendix-III**

**Project 1: (PPREE301)**

**[To be decided by the Department]: Dissertation (Phase-I)**

**Semester-4**

**Project 2: (PPREE401)**

**[To be decided by the Department]: Dissertation (Phase-II)**