**SYLLABUS**

**FOR**

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

**IN**

**ENERGY SYSTEM ENGINEERING**



|  |
| --- |
| **NAAC – A Grade** |

**DEPARTMENT OF ELECTRICAL ENGINEERING**

**COLLEGE OF ENGINEERING & TECHNOLOGY**

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

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

**Bhubaneswar-751029, Odisha, INDIA**

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**COURSE: M. Tech. (EE – Energy Systems Engineering), 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 | PPCEE102 | Power System Dynamics & Control | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 2 | Core 2 | PPCEE105 | Electrical Energy Sources | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 3 | Professional Elective 1  (Any One) | PPEEE102 | Power Electronic Converters | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPEEE104 | Storage Technology |
| 4 | Professional Elective 2  (Any One) | PPEEE106 | Advanced Control Systems | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPEEE107 | Economics & Planning of Energy Systems |
| 5 | Mandatory | PMCMH101 | Research Methodology & IPR | 2 | 0 | 0 | 2 | 30 | 70 | - | 100 |
| 6 | Lab 1 | PLCEE104 | Energy Systems Simulation Lab | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| 7 | Lab 2 | PLCEE105 | Energy System Control 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 | PPCEE205 | Wind Energy Systems | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| 2 | Core 4 | PPCEE206 | Solar Photovoltaic Systems | 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) | PPEEE204 | Probability & Random Processes | 3 | 0 | 0 | 3 | 30 | 70 | - | 100 |
| PPEEE206 | Smart Grid Technology |
| 5 | Practical 1 | PPREE201 | Mini Project with Seminar | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| 6 | Lab 3 | PLCEE205 | Design of Smart Energy Systems Lab | 0 | 0 | 4 | 2 | - | - | 100 | 100 |
| 7 | Lab 4 | PLCEE202 | Renewable 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 |
| PPEEE304 | Electric and Hybrid Vehicles |
| PPEEE303 | Modelling and Simulation |
| 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 System Dynamics and Control (PPCEE102)**

**COURSE OBJECTIVES:**

* To impart knowledge on formation of suitable mathematical model of a given power system stability and Automatic Generation Control of single and multi-area systems.
* To impart knowledge on large signal and small signal stability aspects.
* To impart knowledge on voltage stability issues and methods for finding various stability indicators.

**Syllabus:**

**Module 1:**

**Power System Stability Problems:** Basic concepts and definitions, rotor angle stability, synchronous machine characteristics, power versus angle relationship, modeling of synchronous machines and various loads (composite load model), modeling of excitation systems, turbine and governor systems

**Generation Control Loops:** Automatic Voltage Regulator (AVR) loop, Performance and response of AVR, Automatic Generation Control (AGC) of single and multi-area systems, Static and dynamic response of AGC loops.

**Small Signal Stability:** State space concepts, basic linearization techniques, participation factors, eigen properties of state matrix, small signal stability of a single machine infinite bus system, hoft-bifurcation, electromechanical oscillatory modes

**Module 2:**

**Large Perturbation Stability:** Transient stability: time domain simulation and direct stability analysis techniques (extended equal area criterion), energy function methods: physical and mathematical aspects of the problem, Lyapunov’s method, modeling issues, energy function formulation, potential energy boundary surface (PEBS), energy function formulation of a single machine infinite bus system, equal area criterion and energy function, Transient stability analysis of multi machine systems.

**Module 3:**

**Low Frequency Oscillations:** Power system model for low frequency oscillation study, Eigen value analysis, Improvement of system damping characteristics, Power system stabilizer (PSS) model, Turbine-generator torsional characteristics, shaft system model, torsional natural frequencies and mode shapes, torsional interaction with power system controls; Sub Synchronous Resonance (SSR) and remedial measures.

**Voltage Stability Analysis:** Real and reactive power flow in long transmission lines, Effect of On Load Tap Changing (OLTC) transformers and load characteristics on voltage stability, Voltage stability assessment by P-V curves, Voltage stability limit, Static and dynamic modelling of power systems. Voltage Collapse Proximity Indicators (VCPI), Voltage stability enhancement techniques.

**Suggested Books:**

1. P. Kundur, “Power system stability and control”, McGraw Hill, NY, 1994
2. P. Sauer and M. Pai, “Power System Dynamics an Stability”, Prentice Hall, 1998.
3. A.J. Wood, B.F. Wollenberg “Power generation, operation and control”, John Wiley, 1994
4. K.R. Padiyar, “Power System Dynamics, stability and control”, Interline Publishing, Bangalore, India, 1999
5. M.A. Pai, D.P. Sengupta, K.R. Padiyar, “Small signal analysis of power systems”, Narosa Series in Power and Energy Systems, 2004
6. C. Van Custem, T. Vournas, “Voltage stability of electric power systems”, Riever Academic Press (UK), 1999
7. I.J. Nagrath, D.P. Kothari, “Power system engineering”, Tata McGraw Hill Publishing Co, New Delhi, India, 1994

**COURSE OUTCOMES:**

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

1. gain knowledge on formation of suitable mathematical model of a given power system stability and Automatic Generation Control of single and multi-area systems.
2. gain knowledge on large signal and small signal stability aspects.
3. gain knowledge on voltage stability issues and methods for finding various stability

indicators.

**Core 2: Electrical Energy Sources (PPCEE105)**

**COURSE OBJECTIVES:**

* To provide knowledge, understanding and application oriented skills on conventional and non-conventional sources of energy and relevant technologies towards their effective utilization for meeting energy demand.
* To understand the present scenario for energy conservation and utilization of renewable energy sources for both domestic and industrial applications.
* Analyze the environmental aspects of electrical energy resources.

**MODULE I**

**INTRODUCTION:** Energy and development, units and measurement, conventional and non-conventional sources of energy, fossil, non-fossil and renewable energy resources, Importance of electrical energy in modern industrial society, Usefulness, advantages and disadvantages of energy sources and need of alternative energy sources.

**SOLAR ENERGY:** solar radiation, Solar thermal systems: solar collectors, solar active and passive heating and cooling, solar desalination, solar drying, solar cooking; Applications of solar energy.

**MODULE II**

**FOSSIL FUEL AND HYDRO POWER SOURCES**: Production of Electricity using fossil fuels such as coal, oil and natural gas. Its principle of generation, advantages and disadvantages, Production of Electricity from Hydro resources, Classification of hydropower schemes. Its principle of generation, advantages and disadvantages

**BIOMASS:** Sources, energy plantation, production of fuel wood, conversion techniques; Bio-conversion processes, bio-gas, bio-diesel and ethanol production and utilization; Thermo-chemical processes, biomass gasification, process, types of reactors, utilization of producer gas for thermal and electricity generation.

**MODULE III**

**RENEWABLE SOURCES:** Production of Electricity from Renewable and non-conventional sources such as wind energy, solar energy, biomass, waste, ocean thermal, ocean wave, geothermal, Principle of working of various types of fuel cells, performance and limitations.

**IMPACTS OF ELECTRICAL ENERGY RESOURCES**: Impact of Electrical Energy Generation on Environment and control of pollution from Energy and Electrical Energy Storage systems.

**Text books/ References:**

1. J. Twidell and T Weir, “Renewable energy Recources”, Taylor and Francis group 2007.
2. Renewable Energy- Power for a Sustainable Future, Godfrey Boyle, Oxford University Press.
3. B.H.Khan, Non-Conventional Energy Resources, Tata McGrawHill, 2009.
4. J.A. Duffie and W A Beckman, “Solar Engineering and Thermal Process”, 2nd Edition John Wiley and sons 2001.
5. SP Sukhatme, Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw-Hill,1984
6. G. N. Tiwari and MK Ghosal, “Renewable Energy Resources Basic principles and Application”, Narosa Publishing House 2005.

**COURSE OUTCOMES:**

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

**CO 1:** Know the need of renewable energy resources, historical and latest developments.

**CO 2:** Describe the use of solar energy and various components used in the energy production

with respect to applications like- heating, cooling, desalination, power generation etc.

**CO 3:** Acquire the knowledge of hydro power, biomass, waste to energy, wind, wave power,

geothermal and fuel cells principles and applications.

**CO 4:** Describe the environmental aspects of non-conventional energy resources. In comparison

with various conventional energy systems, their prospects and limitations.

**PE 1: Power Electronic Converters (PPEEE102)**

**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 Cuk SMPS 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

CO 1: Understand and Analyze Power Electronic Converters.

CO 2: Design the switching scheme of SPWM inverters.

CO 3: Acquire the knowledge of controlling DC-DC converters.

**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

o   Electric vehicles - Introduction and types of EV’s

o   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: 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**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **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 |

**PE 2: Economics and Planning of Energy Systems (PPEEE107)**

**COURSE OBJECTIVES:**

* To impart knowledge on market parameters governing economic analysis and energy conservation.
* To impart knowledge on regional and national level energy policies.
* To impart knowledge on various modeling concepts and forecasting methods.

**MODULE I:**

**Introduction:** Law of demand, Elasticities of demand, Theory of firm: Production function, output maximization, cost minimization and profit maximization principles. Theory of market, National income and other macroeconomic parameters.

**Basic concepts of Energy Economics:** Calculation of unit cost of power generation from different sources with examples, Ground rules for investment in Energy sector, Payback period, NPV, IRR and Benefit-cost analysis with example.

**Socio-economic evaluation of Energy Conservation Programmes:** Net Social Benefit incorporating Free riding concept and Rebound effects, Energy-GDP elasticity.

**MODULE II:**

**Overview of Energy Policies:** National energy policy in the last plan periods, Energy use and Energy supply, Overview of renewable energy policy and the Five Year Plan programmes, Basic concept of Input-Output analysis, Concept of energy multiplier and implication of energy multiplier for analysis of regional and national energy policy.

**MODULE III:**

**Models and Analysis:** Analysis of Environmental Pollution through decomposition ofdifferent sectors using I-O model, Interdependence of energy, economy and environment, Modeling conceptsand application of SIMA model and I-O model for energy policy analysis.

**Forecasting of Energy Demand:** Simulation and forecasting of futureenergy demand consistent with macroeconomic parameters in India. Basic concept of Econometrics and statistical analysis (Multiple Regression), Econometrics techniques used for energy analysis and forecasting with case studies from India.

**Reference Books:**

1. EA Diulio, Macroeconomic Theory, Schaum’s Outline Series, 2nd Ed, McGraw-Hill Publishing Company (1990)

2. R Loulou, P R Shukla and A Kanudia, Energy and Environment Policies for a sustainable Future, Allied Publishers Ltd, New Delhi, 1997

3. J Parikh, Energy Models for 2000 and Beyond, Tata McGraw-Hill Publishing Company Ltd, New Delhi,1997

4. Energy Economics -A.V.Desai (Wiley Eastern) Energy Economics - Simple Payback Period, Time Value of Money, IRR, NPV, Life Cycle Costing, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation.

**COURSE OUTCOMES (CO’S)**

1. To gain knowledge on market parameters governing economic analysis and energy conservation.
2. To gain knowledge on regional and national level energy policies.
3. To gain knowledge on various modeling concepts and forecasting methods.

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

**Module I:**

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:**

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:**

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: Energy Systems Simulation Laboratory (PLCEE104)**

LIST OF EXPERIMENTS:

1. Modeling and simulation of a solar PV system different irradiance levels and different temperature.
2. Modeling and simulation of wind energy conversion system for different wind speeds.
3. Modeling and simulation standalone wind -PV hybrid system.
4. simulation of the MPPT for solar PV systems
5. Design and simulation of grid connected wind energy systems with MPPT.
6. Simulation of Load forecasting in micro-grid environment
7. Simulation of Wind power forecasting in micro-grid environment
8. Simulation of Solar power forecasting in micro-grid environment.

**COURSE OUTCOMES:**

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

**CO1:** simulate and characterize Solar PV systems at different environmental situation

**CO2**: Synthesize and harness maximum power at different irradiances and wind velocities

**CO3**: Design wind- PV hybrid systems

**Lab 2: Energy Systems Control Laboratory (PLCEE105)**

**COURSE OBJECTIVES:**

Students should be able to

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

|  |  |
| --- | --- |
| Sl. | 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.

**Audit-1**

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

**Semester-2**

**Core 3: Wind Energy Systems (PPCEE205)**

**COURSE OBJECTIVES:**

1. To provide a broad overview of the technology covering aspects of wind energy conversion systems.
2. To develop clear understanding of the challenges in WECS and its mitigation techniques.

**MODULE-I:**

**Wind Energy Fundamentals:** Wind Energy Basics, Wind Speeds and Scales, Terrain, Roughness, Site Selection, Principles ofAerodynamics of wind turbine blade, Power Content, Betz’s Limit, Instrumentation for wind measurements, Wind data analysis, Wind resource estimation, Turbulence.

**MODULE-II:**

**Classification of Wind Turbines**

Vertical Axis Type, Horizontal Axis, Torque-Speed and Power-Speed Characteristics of Wind Turbines, Constant SpeedConstant Frequency, Variable Speed Variable Frequency, Up Wind, Down Wind; Wind Turbine Control Systems: Pitch Angle Control,Stall Control, Yaw Control and Power Electronic Control, Control strategy.

**MODULE-III:**

**Wind Turbine Generators and Power Electronics Control:** Gear Coupled Generator Type Wind Turbine, Direct Rotor Coupled Generator Wind Turbine, Conversion to Electrical Power: Excited Rotor Synchronous Generator/Permanent Magnet Synchronous Generator, Constructional Features, Steady State Equivalent Circuit Model and Equations, Induction Machines, Constructional Features and Rotating Magnetic Field, Steady State Equivalent Circuit Model and Equations, Doubly Fed Induction Generator, Induction Generator Versus Synchronous Generator.

Types of Power Electronics Converters in Wind Application, Grid Tied Inverter, Power Management, Grid Monitoring Unit (Voltage and Current), Transformer, Power Control, Reactive Power Compensation.

**Hybrid Systems and Grid Integration:** Wind Hybrid Systems, Grid Integration Issues of WECS and its Mitigation Techniques, Cost Economics & Viability of Wind Farm.

**TEXT BOOKS**

1. S. N. Bhadra, D. Kastha, S. Banerjee, Wind Electrical Systems, Oxford Univ. Press, New Delhi, 2005.

2. Wind energy Handbook, Edited by T. Burton, D. Sharpe, N. Jenkins and E. Bossanyi, John Wiley & Sons, 2001.

3. L .L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.

4. Wind and Solar Power Systems, Mukund. R. Patel, 2nd Edition, Taylor & Francis, 2001.

5. D. A. Spera, Wind Turbine Technology: Fundamental concepts of Wind TurbineEngineering, ASME Press.

**REFERENCES**

1. Wind Energy Explained – Theory, Design and Application by J. F. Manwell, J. G. McGowan and A. L. Rogers, John Wiley & Sons, Ltd., 2002.

2. Aerodynamics of Wind turbines by Martin O. L. Hansen, Earthscan, 2008.

3. Anna Mani &Nooley, “Wind Energy Data for India”, 1983.

4. Logan (EARL), “Turbo Machinery Basic theory and applications”, 1981.

5. Wind Turbine Control Systems- Principles, Modelling and Gain Scheduling Design by Fernando D. Bianchi, Hernan De Battista and Ricardo J. Mantz, Springer, 2007.

6. S. Rao & B. B. Parulekar, “Energy Technology”, 4th edition, Khanna publishers, 2005.

7. Renewable Energy- Power for a Sustainable Future, Godfrey Boyle, Oxford University Press.

8. B.H.Khan, Non-Conventional Energy Resources, Tata McGrawHill, 2009.

**COURSE OUTCOMES:**

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

**CO 1**: Conduct a basic wind resource estimation and site assessment.

**CO 2:** Understand the fundamentals of wind turbine design, characteristics and operation.

**CO 3:** Analyze the implementation of wind generators and role of power electronic converters.

**CO 4:** Understand the concept of wind hybrid model and issues related to grid integration with

its mitigation techniques.

**Core 4: Solar Photovoltaic Systems (PPCEE206)**

**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, SharlaveJarosek., “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 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](http://www.amazon.in/s/ref=dp_byline_sr_book_1?ie=UTF8&field-author=ETHEM+ALPAYDIN&search-alias=stripbooks), 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 and classification
2. Apply Fuzzy logic principles to take decisions and design controllers
3. Apply GA principles for solving optimization problems

**MAPPING OF CO WITH PO:**

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

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

**COURSE OBJECTIVE:**

1. Discuss the major components, architecture, communication, interfacing etc. for

an embedded system

1. Implement small programs to solve well-defined problems on an embedded

platform

1. Develop familiarity with tools used to develop in an embedded environment

**Syllabus**

Module -1

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

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

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

**CO2:** 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: Probability and Random Processes (PPEEE204)**

**COURSE OBJECTIVES:**

1. Introduce the topics of probability, random variables, and random processes
2. To familiarize the student to formulate such problems within the framework of probability theory

**Module 1:**

Definitions, Set Theory, Probability Space, Conditional Probability, Combined Experiments, Bernoulli Trials, Bernoulli’s Theorem and Games of Chance

**Module 2:**

Definition of random variables, continuous and discrete random variables, cumulative distribution function (cdf) for discrete and continuous random variables; probability mass function (pmf); probability density functions (pdf) and properties, Jointly distributed random variables, conditional and joint density and distribution, functions, independence; Bayes’ rule for continuous and mixed random variables, Function of random a variable, pdf of the function of a random variable

**Module 3:**

Function of two random variables; Sum of two independent random variables, Expectation: Mean variance and moments of a random variable, Joint moments, conditional expectation; covariance and correlation; independent, uncorrelated and orthogonal random variables Mean vector, Covariance matrix and properties, Some special distributions: Uniform, Gaussian and Rayleigh distributions; Binomial and Poisson distributions

Elements of estimation theory: linear minimum mean-square error and orthogonality principle in estimation; Moment-generating and characteristic functions and their applications; Estimation, Parameter Estimation, Markov Process

**Text Book:**

1. Probability, Random Variables and Stochastic Processes, by Papoulis and Unnikrishnan, Fourth Edition, 2002
2. Liliana Blanco Castaneda, ViswanathanArunachalam and S. Dharmaraja, Introduction to Probability and Stochastic Processes with Applications, Wiley, 2012
3. Kishor S. Trivedi, Probability, Statistics with Reliability, Queueing and Computer Science Applications, 2nd edition, Wiley, 2001
4. Introduction to Probability Models, Sheldon M. Ross, Academic Press, tenth edition, 2009

**COURSE OUTCOMES:**

**CO 1:** Convert an Engineering statement problem into a precise mathematical probabilistic Statement

**CO 2:** Be familiar with some of the commonly encountered random variables

**CO 3:** Be able to obtain the distributions of functions of random variables

**CO 4:** Use statistical principles and the properties of random variables to solve Probabilistic

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

**COURSE OBJECTIVES**

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

**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, Phase Shifting Transformers, Volt/VAr control, High Efficiency Distribution Transformers

**Module-II:**

Geographic Information System(GIS). Intelligent Electronic Devices(IED) & their application for Monitoring & Protection, Storage systems including Battery, SMES, Pumped Hydro. Compressed Air Energy Storage.

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

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

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

**Module-III:**

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.

Advanced Metering Infrastructure(AMI). Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN), Energy Management Systems (SCADA).

**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”,CRCPress, 2009.
3. Stuart Borlase, “ Smart Grid: Infrastructure,Technology and solutions “ CRC Press.
4. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, 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

**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

**Mini Project with Seminar (PPREE201)**

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

**Lab 3: Design of Smart Energy Systems Laboratory (PLCEE205)**

**Course Objectives:**

* To understand the energy system working in a mode with less communication gap or time delay.
* To learn about integration of the smart devices interfaced with IT infrastructure to minimise loss and time delay in bidirectional way. T
* To have brief knowledge of solar system, wind system, hybrid system, grid interconnection system, asynchronous machines, and solar heating.

**Lists of Experiments**

|  |  |
| --- | --- |
| **Sl. No.** | **Name of the Experiment** |
| 1. | Study and analysis of series and parallel connections of solar PV cells and modules. |
| 2. | I-V and P-V characteristics of solar PV under different conditions (ambient, shading, different tilt angle conditions etc.) |
| 3. | Study and performance analysis of single phase inverter for solar PV systems. |
| 4. | Study and performance analysis of battery connected to solar PV systems. |
| 5. | Study and analysis of solar PV grid-connected system. |
| 6. | Study and analysis of wind turbine characteristics. |
| 7. | Study and performance analysis of wind energy system under various loading conditions. |
| 8. | Study of weather condition using different measurement sensors (thermometer, anemometer, pyranometer and humidity sensor). |
| 9. | Study and performance analysis of fuel cells. |
| 10. | Study and performance analysis of hybrid energy system |
| 11. | Study and performance analysis of smart-grid system |
| 12. | Study and performance analysis of micro grid integrated with renewables. |

**COURSE OUTCOMES:**

After completion of course students will be able to:

* + - 1. Apply the knowledge of solar PV system in home integrated system and commercial application of it.
      2. Understand the characteristic wind electricity system and hybrid system.
      3. Conduct practical integration of hybrid system to grid.
      4. Understand various smart devices and its interfacing for smart energy system.

**Lab 4: Renewable Systems Laboratory (PLCEE202)**

COURSE OBJECTIVES:

To educate students on different sources of energy (conventional, non-conventional, renewable, etc.) and their energy content.

To give an exposure of solar energy, wind energy, bio-mass and battery system.

To impart knowledge about the types of load and its generated harmonics.

To train the students for integration of renewable electrical energy sources to the electrical grid and minimise the harmonics for better power quality.

Lists of Experiments

|  |  |
| --- | --- |
| Sl. No. | Name of the Experiment |
| 1. | Calculate the efficiency of solar PV module of your laboratory. |
| 2. | Calculate the fill factor of a solar PV cell. |
| 3. | Develop the P-V and I-V graphs at different insolations/irradiances. |
| 4. | Develop the P-V and I-V graphs at different insolations/irradiances. |
| 5. | Realise the hot spot effect of your laboratory solar PV module. |
| 6. | Calculate the performance parameter of the solar cooker system of your laboratory. |
| 7. | Study and performance analysis of wind power system under various loads. |
| 8. | Study the supply side and load side power factors of a solar PV system. |
| 9. | Study the harmonics present in grid tied solar PV system. |
| 10. | Develop the power curve of wind turbine at various wind velocities. |
| 11. | Study of various softwares related to laboratory experiments |
| 12. | Simulation of power flow of a standalone PV system with a DC load and battery |
| 13. | Simulation of power flow of a standalone PV system with a AC load and battery |
| 14. | Develop the energy density of various energy crops and residues. |
| 15. | Calculate the GCV and NCV of a wood specimen. |

COURSE OUTCOMES:

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

1. Gain knowledge of different renewable sources and its energy content.
2. Perform experiments to measure energy content.
3. Develop the characteristics and performance of renewable technologies especially devoted to production of electricity.
4. Design various loads and characterise its better performance.

**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)**