# M.TECH - RENEWABLE ENERGY TECHNOLOGY

## Department of Electrical and Electronics Engineering

Renewable energy being the most important application area of engineering and technology in the twenty first century, this graduate programme is designed for quality learning in that sector. RE sector needs manpower with design and engineering skills in RE systems and components – this programme targets to impart these. The curriculum has an emphasis on solar and wind energy systems, in tune with the Indian national missions on these. Job avenues targeted are RE equipment manufacturers, farm developers and system operators; also, the qualified human resource requirement in RE teaching and research is potentially high.

The learning is guided through two parallel streams of electrical and mechanical disciplines. Core courses and electives of specialization are offered by faculty from various departments like Electrical and Electronics, Mechanical, Aerospace, Business Management, Science etc.

A Renewable Energy laboratory developed through assistance from C-WET, MNRE and DST, Government of India, equipped with hard and soft experiment systems and real field data collection systems, provides active training support to the programme. Collaborations with global academic and industrial establishments too help in imparting quality learning in this programme

## Program Educational Objectives (PEOs)

- **PEO1:** Graduates will be known for their skill set in the field of research in renewable energy sectors.
- **PEO2:** Graduates will be enriched with blended interdisciplinary knowledge required to establish as an entrepreneur and industry centric in renewable energy.
- **PEO3:** Graduates will be manifested for their adherence to professional, social and ethical responsibilities in implementing sustainable energy solutions.

## Program Outcomes (POs)

- **PO1:** An ability to independently carry out research /investigation and development work to solve practical problems
- **PO2:** An ability to write and present a substantial technical report/document
- **PO3:** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
- **PO4:** Ability to design, implement and perform analysis using cutting edge technologies for harnessing renewable energy in multi-disciplinary applications
- **PO5:** Ability to work in contemporary and futuristic renewable energy research towards industry and society for sustainable energy solutions

# Curriculum

## First Semester

| Course Code | Type | Course Title | LTP | Cr |
|---|---|---|---|---|
| 21MA605 | FC | Probability Statistics and Random Processes | 3-1-0 | 4 |
| 21RE601 | FC | Energy Science and Engineering | 3-0-0 | 3 |
| 21RE602 | SC | Bio, Hydro and Hydrogen Energy Sources | 3-0-0 | 3 |
| 21RE603 | SC | Solar Energy | 3-0-2 | 4 |
| | E | Elective I | 3-0-0 | 3 |
| 21RE681 | SC | Renewable Energy Laboratory | 0-0-2 | 1 |
| 21RM611 | SC | Research Methodology | 2-0-0 | 2 |
| 21HU601 | HU | Amrita Values Program* | | P/F |
| 21HU602 | HU | Career Competency I* | | P/F |
| *Total for Sem I* | | | | **20** |

*Non-Credit Course

## Second Semester

| Course Code | Type | Course Title | L T P | Cr |
|---|---|---|---|---|
| 21RE611 | FC | Energy Economics and Renewable Energy Policy | 3-0-0 | 3 |
| 21RE612 | FC | Electronic Instrumentation Systems | 3-0-2 | 4 |
| 21RE613 | SC | Energy Conservation and Management | 3-0-0 | 3 |
| 21RE614 | SC | Wind Energy | 3-0-2 | 4 |
| | E | Elective II** | 3-0-0 | 3 |
| | E | Elective III | 3-0-0 | 3 |
| | E | Elective IV | 3-0-0 | 3 |
| 21HU603 | HU | Career Competency II | 0-0-2 | 1 |
| 21LIV600 | | **Live in Labs | | |
| *Total for Sem II* | | | | **24** |

## Third Semester

| Course Code | Type | Course Title | L T P | Cr |
|---|---|---|---|---|
| 21RE798 | P | Dissertation I | | 10 |
| *Total for Sem III* | | | | **10** |

## Fourth Semester

| Course Code | Type | Course Title | L T P | Cr |
|---|---|---|---|---|
| 21RE799 | P | Dissertation II | | 16 |
| *Total for Sem IV* | | | | **16** |
| *Total for the programme* | | | | **70** |

## List of Courses

### Foundation Core

| Course Code | Course Title | LTP | Cr |
|---|---|---|---|
| 21MA605 | Probability Statistics and Random Processes | 3-1-0 | 4 |
| 21RE612 | Electronic Instrumentation Systems | 3-0-2 | 4 |
| 21RE611 | Energy Economics and Renewable Energy Policy | 3-0-0 | 3 |
| 21RE601 | Energy Science and Engineering | 3-0-0 | 3 |

### Subject Core

| Course Code | Course Title | LTP | Cr |
|---|---|---|---|
| 21RE603 | Solar Energy | 3-0-2 | 4 |
| 21RE602 | Bio, Hydro and Hydrogen Energy Sources | 3-0-0 | 3 |
| 21RE631 | Soft Computing | 2-0-2 | 3 |
| 21RE613 | Energy Conservation and Management | 3-0-0 | 3 |
| 21RE614 | Wind Energy | 3-0-2 | 4 |
| 21RM611 | Research Methodology | 2-0-0 | 2 |
| 21RE681 | Renewable Energy Laboratory | 0-0-2 | 1 |

### Open Elective

| Course Code | Course Title | LTP | Cr |
|---|---|---|---|
| 21RE631 | Soft Computing | 2-0-2 | 3 |
| 21RE632 | Solar Thermal Engineering | 3-0-0 | 3 |
| 21RE633 | Power Electronics for Energy Systems | 3-0-0 | 3 |
| 21RE634 | Aerodynamics and Wind Turbines | 3-0-0 | 3 |
| 21RE635 | Wind Electric Generators | 3-0-0 | 3 |
| 21RE636 | Applied Computational Fluid Dynamics | 3-0-0 | 3 |
| 21RE637 | Energy Storage Systems | 3-0-0 | 3 |
| 21RE638 | Smart Grid | 2-1-0 | 3 |
| 21RE639 | Electrochemical Energy Systems | 3-0-0 | 3 |
| 21RE640 | Project Management | 3-0-0 | 3 |
| 21RE641 | Energy Forecasting and Modeling | 3-0-0 | 3 |
| 21RE642 | Ocean Energy Conversion | 3-0-0 | 3 |
| 21RE643 | Computational Optimization Theory – Linear and Non-Linear Methods | 3-0-0 | 3 |
| 21RE644 | Electricity Market | 3-0-0 | 3 |
| 21RE645 | Green Building Technologies | 3-0-0 | 3 |

### Project Work

| Course Code | Course Title | L T P | Cr |
|---|---|---|---|
| 21RE798 | Dissertation I | | 10 |
| 21RE799 | Dissertation II | | 16 |

**21MA605 PROBABILITY, STATISTICS AND RANDOM PROCESSES 3-1-0-4**

**Course Objectives:**

To understand and apply the concepts of random variables, distribution functions, statistical estimation and hypothesis testing, correlations, random processes and special processes

**Course Outcome (CO)**

| | |
|---|---|
| CO.1 | Understand the concepts of Random variables of one and two dimensions, the connected probability distributions, mean, variance and their real time applications |
| CO.2 | Establish of the significance of the theory of estimation, Test of Hypothesis, Interval Estimation, etc. |
| CO.3 | Build knowledge related to linear relationship between two random variables using correlation |
| CO.4 | Understand the basic concepts of the random process, stationarity and autocorrelation functions and properties |
| CO.5 | Establish the concepts of spectrum estimation and spectral density of random process |
| CO.6 | Illustrate the Markov process and chain and its significance in practical problems. |

**CO-PO Mapping:**

| CO | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 1 | | | | |
| **CO.2** | 2 | 1 | 2 | | |
| **CO.3** | 2 | 1 | | | |
| **CO.4** | 2 | | | | |
| **CO.5** | 2 | 1 | 2 | 1 | 1 |
| **CO.6** | 2 | 1 | 2 | 1 | 1 |

**Syllabus:**

Review: Sample Space and Events, Interpretations and Axioms of Probability, Addition rules, Conditional Probability, Multiplication and Total Probability rules, Independence, Bayes theorem.

Probability and Statistics: Discrete Random variables, Probability Distributions and Probability mass functions, Cumulative Distribution functions, mathematical expectation and variance, Standard distributions - discrete distributions - binomial, Poisson and geometric distributions - continuous distributions - uniform, exponential, Normal distributions - Chebyshev’s theorem. Joint, marginal and conditional probability distributions for discrete and continuous cases, independence, expectation of two-dimensional random variables, conditional mean and variance and covariance. Correlation, properties of correlation coefficient. Point Estimation, Sampling Distributions and Central limit theorem, Method of Maximum likelihood Estimation -Confidence Interval on the mean of a Normal Distribution with Variance known and unknown. Hypothesis Testing, Tests on the Mean of a Normal Distribution.

Random Processes: General concepts and definitions-Stationarity in random process- autocorrelation and properties-Poisson points, Poisson and Gaussian processes-Spectrum estimation- Ergodicity and mean Ergodic theorem-Power spectral density and properties. Markov processes –Markov Chains – Transition Probability matrix-Classification of states-Limiting Distributions.

***Skill development and Employability:*** *Understand and apply random variables, statistical distributions, expectations, sampling distributions, estimation, statistical hypothesis testing, correlations, random functions and processes in science and technology applications.*

**TEXT BOOKS / REFERENCES:**


1. Douglas C. Montgomery and George C. Runger, “Applied Statistics and Probability for Engineers”, Sixth Edition, Wiley, 2016.
2. Roy D. Yates, “Probability and Stochastic Processes A Friendly Introduction for Electrical and Computer Engineers” Second Edition John Wiley and Sons Inc., 2005.
3. Ravichandran, J. “Probability and Statistics for Engineers”, Wiley India, 2012.
4. Ravichandran, J “*Probability and Random Processes for Engineers*”, First Edition, IK International, 2015.
5. Papoulis, A and Unnikrishna Pillai, “*Probability, Random Variables and Stochastic Processes*”, Fourth Edition, McGraw Hill, 2002.

**21RE601** **ENERGY SCIENCE AND ENGINEERING** **3-0-0-3**

**Course Objective:**

- Understand the fundamentals of photosynthetic, photocatalytic and photoelectrochemical systems and devices for the efficient energy and fuels production.
- Learn the principles and operations of electrochromic devices, PV integrated electrochromic smart windows for the use in energy efficient building constructions.

**Course Outcome:**

CO.1 Understand the basics of renewable, biomass energy sources and relevant thermodynamics

CO.2 Understand and correlate the materials and devices following the underlying principles of photosynthetic processes for the efficient solar energy conversion.

CO.3 Learn the fundamentals of different photochemical and photoelectrochemical systems known for the efficient energy and fuels productions.

CO.4 Apply the concepts of oxide electrochromic devices and PV integrated electrochromic smart windows for the construction of energy efficient and green buildings.

**CO-PO Mapping:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 2 | 2 | 1 | 1 | |
| **CO.2** | 2 | 2 | 1 | 1 | 1 |
| **CO.3** | 2 | 2 | 2 | 3 | 3 |
| **CO.4** | 2 | 2 | 2 | 3 | 3 |

**Syllabus:**

Historical development of commercial energy supply: Commercial energy in ancient times, Renewable Energy utilization in ancient times, Industrial revolution, Realization of environmental concerns, Developments in Renewable Energy Sector. Energy from biomass: sources, classification, conversion into fuels, photosynthesis, C3 and C4 plants on biomass production, physicochemical characteristics; CO2 fixation potential. Fundamentals of thermodynamic cycles – power and refrigeration cycles – Rankine cycle – components of a power plant – cogeneration

Fundamentals of photosynthetic processes-Photochemical hydrogen generation-Photoelectrochemical systems – solar cells and solar fuels production. Oxide semiconductors (ZnO, $TiO_2$, $Fe_2O_3$, $WO_3$, etc) photocatalysts-Non oxide semiconductor materials for water splitting. Nanostructured semiconducting materials - Photocatalytic mechanisms. Photochemical cell designs, performance, and diagnosis for efficient solar hydrogen production.

Electrochromic systems-Oxide electrochromics-Flexible polymer electrochromic devices-Photovoltaic-integrated electrochromic smart windows-Electrochromic smart windows for dynamic day light control in buildings-Life cycle analysis of smart windows.

*Skill Development and Employability: Bridge the knowledge of material physics, renewable energy evolution, energy from biomass and thermodynamic principles.*

TEXT BOOKS/REFERENCES:


1. Sorensen B., "*Renewable Energy*" Second Edition, Academic Press, 2000
2. Neelu Chouhan, Ru-Shi Liu, Jiujun Zhang, *Photochemical Water Splitting Materials and Applications*, ISBN 9780367869915, CRC Press, 2019.
3. Rajeshwar, K., McConnell, R., Licht, S., *Solar Hydrogen Generation*, ISBN 978-0-387-72810-0, Springer-Verlag New York, 2008.
4. Roger J. Mortimer, David R. Rosseinsky, Paul M. S. Monk, *Electrochromic Materials and Devices*, ISBN 9783527336104, Wiley-VCH Verlag GmbH & Co, 2015.
5. Soli J. Arceivala, "Green Technologies for a better Future", McGraw Hill Education (India) Private Ltd., New Delhi 2014.

**21RE602 BIO, HYDRO AND HYDROGEN ENERGY SOURCES 3-0-0-3**

**Course Objectives:**

- Learn principles of extraction of energy from biomass and water
- Design bio and hydro power conversion systems

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understanding the principles of extraction of energy from biomass and water |
| CO.2 | Familiarity with various biomass conversion processes |
| CO.3 | Illustrate bio, hydro, hydrogen and ocean power generation systems |
| CO.4 | Model hydro power extraction from oceans |

**CO-PO Mapping:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 1 | | | | |
| **CO.2** | 2 | | 2 | 2 | 2 |
| **CO.3** | 2 | | 2 | 2 | 1 |
| **CO.4** | 2 | | 2 | 2 | 2 |

**Syllabus:**

Biomass resource assessment, biomass productivity study, waste land utilization through energy plantation. Biomass conversion process: biochemical - anaerobic digestion, biogas production mechanism and technology, types of digesters, design of biogas plants; chemical - hydrolysis and hydrogenation, bio-fuels, Biodiesel production, fuel characteristics; thermochemical - pyrolysis, combustion and gasification, gasifiers: updraft, downdraft, fluidized bed, biomass carbonization, natural draft and gasification based biomass stoves, gasification based power generation. Design of power plants. Hydrology, Selection of site, Resource assessment, Classification of Hydropower Plants, Small Hydropower Systems: mini, micro and pico systems, Pumped storage plants, Hydraulic Turbines: classification and operational aspects, elements of turbine, selection and design criteria, Planning of power house, Hydro power from oceans – Wave and Tidal power, Electronic load controller; environmental issues related to hydro projects. Modeling biomass, hydro and ocean energy conversion system using simulation tools. Green hydrogen generation from bio-methane.

***Skill development and Employability****: Design and simulate bio and hydro power conversion systems using simulation tools.*

**TEXT BOOKS/ REFERENCES:**

1. Sorensen B., "*Renewable Energy*", Fifth Edition, Academic Press, 2017.

2. Ravindranath N. H. and Hall D. O., "*Biomass, Energy and Environment*", Oxford University Press, 1995.

3. Rosillo-Calle F. and Francisco R., "*The Biomass Assessment Handbook: Bioenergy for a Sustainable Environment*", Earthscan, 2007.

4. Wagner H. and Mathur J, "*Introduction to Hydro Energy Systems: Basics, Technology and Operation*", Springer, 2011.

5. John Twidell and Tony Weir, "Renewable Energy Resources", Second Edition, Taylor and Francis, 2005.

6. M. M. Dandekar and K. N. Sharma, "Water Power Engineering", Vikas Publishing House Pvt. Ltd., Second Edition, 2014.

**21RE603** **SOLAR ENERGY** **3-0-2-4**

**Course Objectives:**

- Understand the fundamentals of solar energy conversion and familiarize with solar geometry
- Design PV systems and analyse performance
- Familiarize with solar energy policies, costing and PV system designing software

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understand the properties of solar energy resource, PV and ST system operation and component specifications |
| CO.2 | Compute circuit parameters, solar geometry and cell/array performance parameters |
| CO.3 | Understand PV installations, government policies and costing |
| CO.4 | Design of PV systems for domestic, commercial and industrial applications |
| CO.5 | Analyse the PV systems performance based on performance indices |
| CO.6 | Apply hardware balance of system components and Solar PV system designing software |

**CO-PO MAPPING**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 3 | | 3 | | 3 |
| **CO.2** | 3 | 2 | 3 | 1 | 3 |
| **CO.3** | 3 | | 3 | | 3 |
| **CO.4** | 3 | | 3 | 2 | 3 |
| **CO.5** | 3 | 2 | 3 | 1 | 3 |
| **CO.6** | 3 | 2 | 3 | 1 | 3 |

**Syllabus:**

History of Solar Energy, Properties of Sun Light- Solar Radiation - Solar Radiation– Atmospheric effects - Solar Geometry - Measuring Instruments - Estimation of Solar Radiation - Solar Geometry- Tilt angle calculation and Sun Tracking- Solar Radiation map.

Solar cell physics & characteristics – dark and illuminate junctions, parasitic resistances, PV cell architecture and fabrication steps- Type - crystalline Si substrates, thin film deposition, amorphous Si, CIGS, CdTe etc., dye sensitized cell. Solar thermal characteristics, laminates on the plate

Characteristics of PV cell- PV Module and Array –Bypass and blocking diodes, Irradiance and temperature effects, STC and NOCT conditions, Maximum power point. Effect of shading.

Balance of system components and their design –MPPT Algorithms. Stand Alone PV System – batteries and its characteristics- charge controllers, Hybrid PV Systems.

Grid Connected PV System, Installation of SPV Systems- inverter selection, cable sizing, grounding; Cost analysis and pay back calculations; Concept of feed in tariffs. Environmental and safety issues.

Introduction to solar Thermal Systems: Solar Thermal Collector and its types, Solar-thermal Energy Storage System, Applications of Solar Thermal System. Testing

Software used in PV system planning – PVsyst, Helioscope, PVSol

***Skill development and Employability****: Design PV systems using designing software and familiarize with solar energy policies and costing.*

**TEXT BOOKS/ REFERENCES:**


1. Nelson J, "*The Physics of Solar Cell*", Imperial College Press, 2006.
2. Wenham SR, "*Applied Photovoltaic*", Second Edition, Earthscan Publications Ltd, 2007.
3. G.N. Tiwari, "*Solar Energy-Fundamentals, Design, Modeling and Applications*", Narosa Publishers, 2002.
4. D. Goswami, F. Kreith and J.F. Kreider, "*Principles of Solar Engineering*",Second Edition, CRC press, 2000.
5. John Twidell and Tony Weir, "*Renewable Energy Resources*", Second Edition, Taylor and Francis, 2005.

**21RE681 RENEWABLE ENERGY LABORATORY 0-0-2-1**

Matlab, PSpice, PSCAD, EMTDC, DigSILENT, ANSYS and EMTP – applications in electric power system, SPV system and solar/bio thermal systems.

**Course Outcome(CO)**

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

**CO-PO MAPPING:**

| CO-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 3 | 2 | 3 | 1 | 3 |
| **CO.2** | 3 | 2 | 3 | 1 | 3 |
| **CO.3** | 3 | 2 | 3 | 1 | 3 |
| **CO.4** | 3 | 2 | 3 | 1 | 3 |

***Skills development and Employability****: Use domain specific software and instruments used in the renewable energy sector*

**21RM611** **RESEARCH METHODOLOGY** **2-0-0-2**

**Course Objectives:**

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

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understand types and methods of research, modeling, |
| CO.2 | Analyse experimental results |
| CO.3 | Prepare and present research papers |
| CO.4 | Knowledge on IPR and ethics in publication |

**CO - PO mapping:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO1** | 1 | 3 | 1 | | 1 |
| **CO2** | 1 | 3 | 2 | | |
| **CO3** | 2 | 3 | 2 | 1 | |
| **CO4** | 2 | 3 | 1 | 1 | 1 |

**Syllabus:**

**Unit I:**

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

**Unit II:**

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

**Unit III:**

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

**Unit IV:**

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

**Unit V:**

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

***Skill development and Employability:*** *Develop presentation skills, analyse the results, technical writing skills in reports and research papers, understand the purpose of IPR and ethics in research and publication.*

**TEXT BOOKS/ REFERENCES:**

1. Bordens, K. S. and Abbott, B. B., "*Research Design and Methods – A Process Approach*", 8thEdition, McGraw-Hill, 2011.

2. C. R. Kothari, "*Research Methodology – Methods and Techniques*", 2nd Edition, New Age International Publishers, 2004.

3. Davis, M., Davis K., and Dunagan M., "*Scientific Papers and Presentations*", 3rd Edition, Elsevier Inc.

4. Michael P. Marder," *Research Methods for Science*", Cambridge University Press, 2011.

5. T. Ramappa, "*Intellectual Property Rights Under WTO*", S. Chand, 2008.

6. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "*Intellectual Property in New Technological Age*". Aspen Law & Business; 6th Edition July 2012.

**21RE611 ENERGY ECONOMICS AND RENEWABLE ENERGY POLICY 3-0-0-3**

**Course Objectives:**

- To understand the basic concepts of Energy Economics
- To assess the economic performance of energy business
- To familiarize the national and international RE policies

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understanding of the basic economics concepts of demand, production and cost |
| CO.2 | Computation of time value of money |
| CO.3 | Assessment of economic performance of industry/business |
| CO.4 | Understand global and national energy policies |
| CO.5 | Techno-economic analysis of energy production/supply systems |

**CO-PO Mapping:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | | | 2 | | |
| **CO.2** | 1 | | 2 | | |
| **CO.3** | 3 | | 3 | | |
| **CO.4** | 1 | | 2 | | 3 |
| **CO.5** | 3 | | 3 | 1 | |

**Syllabus:**

Energy economics: Basic concepts, Energy data and energy balance. Energy Accounting framework; Economic theory of demand, production and cost market structure.

Costing: Time value of money – present worth and future worth; Economic performance indices – simple and discounted payback, Equivalent Annual Cost, Levelised cost - calculation of unit cost of power generation, life cycle cost, cost-benefit ratio, E/D ratio, net present value, Internal rate of return. Modified internal rate of return (MIRR), Debt to equity ratio, Debt service coverage ratio, Profitability Index, Sensitivity Analysis.

Energy-GDP elasticity; National and regional energy policies - RE certificate, RE purchase obligation, subsidy and taxation, Renewable Recovery Fund, Energy Exchange- Deviation Settlement Mechanism- deregulated power market, electricity regulations, Grid Code, International RE policy, Case studies.

Energy- Environment interactions at different levels; Energy security issues.

***Skill development and Employability**: Ability to evaluate economic feasibility of renewable energy project in line with the national and global standards and policies.*

**TEXT BOOKS/ REFERENCES:**


1.Bhattacharyya S. C., "*Energy Economics*", Springer, 2011.

2.Ferdinand E. B., "*Energy Economics: A Modern Introduction*", Kluwer, 2000.

3.Kandpal T. C. and Garg H. P., "*Financial Evaluation of Renewable Energy Technology*", Mac Milan, 2003.

4.Munasinghe M. and Meier P., "Energy Policy Analysis and *Modeling*", Cambridge University Press, 1993.

**21RE612 ELECTRONIC INSTRUMENTATION SYSTEMS 3-0-2-4**

**Course Objectives:**

- To understand the requirements of measurement and instrumentation and to learn the principles of transducers.
- To familiarize the microcontrollers, PMU, PLC, SCADA and other communication interfaces used in industrial measurements and applications.

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | To demonstrate the basic concepts of measurement and instrumentation systems |
| CO.2 | To demonstrate the operation and specifications of Transducers |
| CO.3 | Apply SCADA, PMU and microcontrollers for measurement and control |
| CO.4 | Apply PLC for control applications and understand different communication techniques |

**CO-PO Mapping:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 2 | 2 | | | |
| **CO.2** | 2 | 2 | | | |
| **CO.3** | 3 | 2 | 2 | 1 | 1 |
| **CO.4** | 3 | 2 | 2 | 1 | 1 |

**Syllabus:**

Unit 1: Measuring systems - classification, static and dynamic characteristics, errors, calibration and standards, Torque measurement and Vibration measurement. Anemometers – cup, hot wire, SODAR, LIDAR. Sunshine recorder, pyranometer, pyroheliometer and GIS.

Unit 2: Passive electrical transducers, Resistive, thermal radiation detectors, resistive strain, resistive pressure, linear variable differential transformer. Active electrical transducers, Thermoelectric-thermocouples, RTD, piezoelectric, Hall Effect, photo electric, Level and flow measurements

Unit 3: SCADA, Smart meters (net metering), Phasor measurement unit, basic measurements/sensing with ADC, CCP modules in PIC microcontrollers. PLC: architecture, programming and ladder diagram. Communication Technologies: wired, wireless. RF-Zigbee, Bluetooth, WiFi, Ethernet, GSM, GPRS, Data acquisition systems, data loggers. Overview of IoT and Industry 4.0

***Skill development and Employability:*** *Design signal conditioning circuits, transducers and microcontroller-based measurements and communication interfaces used in industrial applications.*

**TEXT BOOKS / REFERENCES:**

1. D.V.S. Murty, "*Transducers and Instrumentation*", Second Edition, Prentice-Hall of India Private Limited, 2008.

2. Arun K. Ghosh, "*Introduction to Measurements and Instrumentation*", Fourth Edition, PHI Learning Private Limited, 2012.

3. S. K. Singh, "*Computer Aided Process Control*", Prentice-Hall of India Private Limited, 2003.

4. William Stallings, "*Wireless Communications and Networks*", Second Edition, Pearson Education, 2005.

**21RE613 ENERGY CONSERVATION AND MANAGEMENT 3-0-0-3**

**Course Objectives:**

- Estimate energy efficiency in electrical equipment as well as in thermal fuels and combustion systems
- Learn energy conservation opportunities and techniques in domestic, commercial and industrial sectors
- Familiarize with energy audit

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understand and analyse energy scenario and policies of India and World in the past, present and future. |
| CO.2 | Estimate energy efficiency in electrical appliances and thermal systems |
| CO.3 | Evaluate techno-economic feasibility of various energy efficiency improvement opportunities in domestic, commercial and industrial sectors |
| CO.4 | Synthesis of industrial energy subsystem models |
| CO.5 | Analyse energy audit observations |

**CO-PO Mapping:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | | 1 | 1 | 3 | |
| **CO.2** | 3 | 1 | 3 | | |
| **CO.3** | 3 | 1 | 3 | 3 | 2 |
| **CO.4** | 3 | 1 | 3 | | 1 |
| **CO.5** | 3 | 2 | 3 | 3 | |

**Syllabus:**

Concept of Energy Efficiency and Clean Production. Energy Conservation Act 2001 and its features. Energy Conservation Policies and Regulations.

Energy conservation on demand side: Efficient Lighting; Energy Efficiency in motors, pumps and fans. Power quality issues related to Energy Efficient Technologies. Energy saving and trading Evaluation of thermal performance – calculation of heat loss – heat gain, estimation of heating & cooling loads, factors that influence thermal performance, waste heat recovery and co-generation, analysis of existing buildings setting up an energy management programme – electricity saving techniques.

Energy Management in Electrical Power Systems: Demand Response; Microgrids and Smart grid. DC microgrids and energy efficiency

Energy Management and Audit: Functions and methodologies of preliminary as well as detailed energy audits; Pre-audit, audit and post-audit measures Instruments for energy audit, Energy Service Companies (ESCOs), Energy Conservation Practice – Case Studies. Overview of Block Chain Technology, Renewable energy large capacity grid support using batteries.

***Skill development and Employability:*** *Familiarize as Energy Managers in Industries, Energy Auditors in energy auditing firms under energy conservation projects and acquainted to apply for certificate exam conducted by Bureau of Energy Efficiency (BEE).*

**TEXT BOOKS/ REFERENCES:**


1.Hamies, "*Energy Auditing and Conservation; Methods, Measurements, Management and Case Study*", Hemisphere Publishers, Washington, 2003.

2. C.W. Gellings and J.H. Chamberlin, "*Demand-Side Management Planning*", 2nd Edition, Prentice Hall, 1993.

3.Wayne C Turner, "*Energy Management Handbook*",9th Edition, River Publishers, 2018.

4. Bureau of Energy Efficiency Study Material for Energy Managers and Auditors Examination: Paper I to IV, www.energymanagertraining.com

5. S. Pabla, "*Electric Power Systems Planning*", 2nd Edition,McGraw Hill, Second Edition, 2015

6. Moncef Krarti, "*Energy Audit of Building Systems: An Engineering Approach*", Third Edition, CRC Press,2020.

7. Amit K. Tyagi, "*Handbook on Energy Audits and Management*", TERI, 2003.

**21RE614** **WIND ENERGY** **3-0-2-4**

**Course Objectives:**

- Learn wind regime modeling and resource assessment
- Learn basic principles and operational features of wind turbines and WTG
- Familiarize with grid connected and off grid applications of wind energy
- Conduct performance analysis of WECS

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understand wind resource, principles of conversion and technologies |
| CO.2 | Develop wind regimes and assessment of wind resource |
| CO.3 | Understand the operation and constraints of wind turbine generators |
| CO.4 | Illustrate the operation of the grid connected and off grid applications of wind energy |
| CO.5 | Analyze the performance of WECS |
| CO.6 | Develop hardware related to system components and software tools for the design, analysis and assessment of wind energy resources |

**CO-PO MAPPING:**

| CO-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 3 | | 3 | | |
| **CO.2** | 3 | 1 | 3 | 1 | 3 |
| **CO.3** | 3 | | 3 | | |
| **CO.4** | 3 | | 3 | 2 | 3 |
| **CO.5** | 3 | 1 | 3 | 1 | 3 |
| **CO.6** | 3 | 2 | 3 | 1 | 3 |

**Syllabus:**

Wind resource assessment - History of wind energy-current status and future prospects of wind energy in India- Power available in wind- Meteorology of wind: Wind Regime modelling/Analysis of wind regimes

Global circulation, Forces influencing wind, Wind shear and turbulence effect-Measurement of wind -wind speed statistics-time and frequency distribution- Weibull and Rayleigh distribution and parameter estimation

Local Wind systems, Wind Rose. Energy estimation of wind regimes.

Wind Turbines: Types, components; Horizontal and vertical axis wind turbines, Power in the wind, Power extracted from wind, Betz limit, Airfoil Lift and drag characteristics, thrust and torque, stream tube model, linear momentum theory, power coefficient, thrust coefficient, axial interference factor. Tip-speed ratio characteristics Pitch and stall regulation, power curve, energy calculation.

Wind turbine generators: stand-alone systems –wind pumps and small wind turbine - schemes and system design, grid-connected systems –types, topology, characteristics, fixed speed and variable speed systems. Power electronic interface.

Wind farm development and operation: Techno economic feasibility. Government regulations and guidelines, micro-siting and layout, use of software in micro-siting, selection of equipment, installation and commissioning. Local infrastructure and power evacuation, influence of grid quality and reliability. Operation and maintenance. Central monitoring system and SCADA.

Windfarm performance indices. Economic performance indices. Offshore wind farm development and special considerations. Short term and long-term Wind forecasting. Grid code for wind farm operation.

***Skill development and Employability:*** *Familiarize with grid connected and off grid applications of wind energy and conduct techno economic aspect, micro-siting, forecasting and performance analysis of WECS using domain specific software used under wind sectors.*

**TEXT BOOKS/ REFERENCES:**


1. Joshua Earnest, "*Wind Power Technology*", Third Edition, PHI Learning Pvt. Ltd., New Delhi, 2019.
2. Sathyajith Mathews, "*Wind Energy: Fundamentals, Resource Analysis and Economics*", Springer, 2006.
3. Joshua Earnest and Tore Wizelius, "*Wind Power Plants and Project Development*", Second Edition, PHI Learning Pvt. Ltd., New Delhi, 2017.
4. G L Johnson, "*Wind Energy Systems*", Manhattan, KS, 2004.
5. E. H. Lysen, "*Introduction to Wind Energy, CWD Report 82-1, Consultancy Services Wind Energy Developing Countries*", The Netherlands, May 1983.
6. ErichHau, "*Wind Turbines- Fundamentals: Technologies, Application, and Economics*". Springer -Verlag Berlin -Heidelbeg, 2000.
7. D.P. Kothari and S. Umashankar, "*Wind Energy Systems and Applications*", Alpha Science International, 2014.
8. Pramod Jain, "*Wind Energy Engineering* ", McGraw Hill, New Delhi, 2011.

**21RE631 SOFT COMPUTING 2-0-2-3**

**Course Objectives:**

- Understand Soft Computing concepts, technologies, and applications
- Understand different soft computing tools to solve real life problems
- Introduce the field of Machine Learning and its applications

**Course Outcome (CO)**

| | |
|---|---|
| CO.1 | Solve engineering problems with uncertainty using fuzzy logic technique |
| CO.2 | Apply neural networks to pattern classification and regression problems |
| CO.3 | Apply evolutionary algorithms to solve optimization problems. |
| CO.4 | Enable skills to solve complex real-world problems using soft computing techniques |

**CO-PO Mapping:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| CO1 | 2 | 2 | 2 | | |
| CO2 | 2 | 2 | 2 | | |
| CO3 | 2 | 2 | 2 | | |
| CO4 | 3 | 3 | 3 | 1 | 2 |

**Syllabus:**

Classical set – operations – Fuzzy set – Operations – Relation – Fuzzy Logic (FL) – Membership Functions – Fuzzifications and Defuzzifications – Fuzzy Relations – TSK Fuzzy Modeling. Neural Networks (NN) – Supervised and Unsupervised Learning – Hopfield – RBF Networks

Kohonen Self Organizing Networks – Learning Vector Quantization – Hebbian Learning.
Neuro-fuzzy models- adaptive neuro-fuzzy inference system (ANFIS)- Architecture – Hybrid Learning Algorithm – Learning Methods that Cross-fertilize ANFIS and RBFN - Applications.

Introduction to Support Vector Machines – Classification and Regression
Optimization Problem – Genetic Algorithm - Ant colony optimization.
Typical Applications Integrating Various Soft Computing Tools. Introduction to Machine learning.

***Skills development and Employability****: Solve real time problems using soft computing techniques using simulation tools. Apply optimization techniques using simulation tools.*

**TEXT BOOKS/ REFERENCES:**


1. Timothy Ross, "*Fuzzy Logic with Engineering Applications*", Fourth Edition, John Wiley and sons, 2016.
2. Simon Haykin, "*Neural Networks and Learning Machines*", Third Edition, Pearson Education, 2009.
3. K.F. Man, K.S. Tang and S. Kwong, "*Genetic Algorithms: Concepts and Applications*", IEEE Transactions Industrial Electronics, Vol. 3, 1996.
4. Nello Cristianini and John Shawe-Taylor, "An Introduction to Support Vector Machines and Other Kernel-based Learning Methods", Cambridge University Press, 2013.

**21RE632** **SOLAR THERMAL ENGINEERING** **3-0-0-3**

**Course Objectives:**

- Learn the concepts of thermodynamics and heat transfer in buildings, heat exchangers.
- Design solar thermal collectors for various applications and evaluate performance

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understand the concepts of thermodynamics and heat transfer |
| CO.2 | Apply the principles of thermodynamics in energy transfer |
| CO.3 | Analyse heat transfer in buildings and heat exchangers |
| CO.4 | Apply principles to collect and measure the solar thermal form of energy |
| CO.5 | Evaluate the performance of solar thermal collectors and energy systems under various applications |

**CO-PO Mapping:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 3 | | 2 | | 1 |
| **CO.2** | 2 | | 3 | 1 | 1 |
| **CO.3** | 2 | | 2 | | 1 |
| **CO.4** | 2 | | 2 | 1 | 2 |
| **CO.5** | 2 | | 2 | 1 | 2 |

**Syllabus:**

Fundamentals of Thermodynamics and Heat Transfer: Basics of thermodynamics up to second law – Laws of Thermodynamics – Heat engines, refrigerators and heat pumps; thermodynamic cycles-power and refrigeration cycles; Laws of heat transfer – Thermal resistance network – Heat conduction equation – Critical radius of insulation – Initial and Boundary conditions; Non-dimensional Numbers in heat transfer; Heat transfer from extended surfaces; Heat Exchangers: Types and applications – Overall heat transfer coefficient – LMTD and NTU methods.

Solar radiation measurement instruments – Pyranometer & Pyrheliometer; Solar Thermal Collectors – Liquid Flat plate collector construction and analysis – Thermal resistance network model – Heat transfer correlations – performance characteristics and factors affecting – Concentrating type collectors – Construction and working – Tracking mechanisms – Heliostats with central receiver –Solar Process Loads – Collector Heat Exchanger Factor, Collector Arrays - Series Connections, Series Arrays with Sections Having Different Orientations. Solar thermal applications – Solar water heaters – Space heating – Active and passive heating – Solar air heaters – Solar chimney; Solar thermal power plants – Low, medium and high temperature systems –

Performance analysis; Solar Ponds – Convective and non-convective ponds – Salt gradient solar pond – Experimental studies; Water desalination using solar still; Space cooling and refrigeration.

***Skill development and Employability:*** *Design measurement instruments and solar thermal collectors used for various applications and evaluate its performance.*

**TEXT BOOKS/ REFERENCES:**

1. John A. Duffie and W. A. Beckman, "*Solar Engineering of Thermal Processes*", John Wiley and Sons, 2013.
2. F.P. Incopera and D.P. Dewitt, "*Fundamentals of Heat Transfer*", John Wiley and Sons, 2011.
3. John Twidell and Tony Weir, "*Renewable Energy Resources*", Fourth Edition, Taylor and Francis, 2015.
4. Y. A. Cengel & M. A. Boles, "Thermodynamics – *an engineering approach*," Nineth Edition, McGraw Hill education, 2019.
5. A. Cengel& A. J. Ghajar, "Heat and Mass Transfer," Sixth Edition, McGraw Hill education, 2020.

**21RE633 POWER ELECTRONICS FOR ENERGY SYSTEMS 3-0-0-3**

**Course Objectives:**

- To Understand the characteristics of power electronic components and various converters and voltage regulators
- To develop power electronics and switching mode power converters for renewable energy applications

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understand the characteristics of power semiconductor switches, various converters and voltage regulators |
| CO.2 | Analyse the operation of various converters, and voltage regulators under continuous conduction mode with R, RL & RLE loads |
| CO.3 | Design various converters for voltage regulation and variable voltage- variable frequency applications |
| CO.4 | Control the converters in grid synchronization applications for power flow control. |

**CO-PO Mapping:**

| CO-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 3 | | 2 | 1 | 1 |
| **CO.2** | 3 | | 3 | | 2 |
| **CO.3** | 3 | 1 | | | 2 |
| **CO.4** | 3 | | 2 | 1 | 2 |

**Syllabus:**

Power semiconductor switches: Power diodes, Thyristors, MOSFETS, and IGBT. Switch waveforms and power loss calculations. Non sinusoidal waveform analysis -Harmonic standards

AC voltage controllers: Thyristor controlled reactor (Reactive power compensation in wind electric generator systems) -Soft starters for Wind electric systems.

Converters: AC-DC converters and Design of DC–DC converters (For Solar PV & Wind energy applications). Isolated and Non-isolated DC-DC Converters- performance parameters.

Inverters: Single phase and three phase sine PWM inverters –design of dc link voltage -Harmonic analysis -rectifier mode of operation-AC-DC-AC back-back converters in renewable energy applications (Off and on grid) -Grid synchronization and PLL-Islanding operation. Filter design. Relevant IEEE and IEC standards for renewable energy systems. Grid support features of utility-scale PV with storage, Microgrids, and frequency/voltage control in islanded mode of operation, HVRT and LVRT capability for wind and solar, Demand response, distributed storage and smart grid concepts.

***Skill development and Employability:*** *Familiarise with semiconductor devices and design converters for voltage regulation and Variable Voltage Variable Frequency (VVVF) applications in renewable sector.*

**TEXT BOOKS/ REFERENCES:**


1. Mohan, T.M.Undeland, and W.P.Robbins, "*Power Electronics, Converters, Applications and Design*", Fourth Edition, John Wiley and Sons Inc., 2017.
2. Teodorescu, Remus, Marco Liserre, and Pedro Rodriguez. *Grid converters for photovoltaic and wind power systems*. Vol. 29. John Wiley & Sons, 2011.
3. Abu-Rub, Haitham, Mariusz Malinowski, and Kamal Al-Haddad. *Power electronics for renewable energy systems, transportation and industrial applications*. John Wiley & Sons, 2014.
4. Simões, Marcelo G., and Sudipta Chakraborty. *Power Electronics for Renewable and Distributed Energy Systems: A Sourcebook of Topologies, Control and Integration*. Springer-Verlag London, 2013.
5. Nicola Femia, Giovanni Petrone, Giovanni Spagnuolo, Massimo Vitelli. *Power Electronics and control for maximum Energy Harvesting in Photovoltaic Systems*. First Edition. e – Book. 2017.

**21RE634 AERODYNAMICS AND WIND TURBINES 3-0-0-3**

**Course Objectives:**

Learn aerodynamics principles leading to the testing, analysis and design aspects of wind turbine blades.

**Course Outcome (CO)**

| | |
|---|---|
| CO.1 | Understand the basic terminologies and concepts in aerodynamics |
| CO.2 | Understand and apply potential flow theory to various two-dimensional problems |
| CO.3 | Understand aerofoil characteristics and nomenclature of well-known NACA aerofoils |
| CO.4 | Understand Prandtl's lifting line theory for finite wings |
| CO.5 | Illustrate viscous flow and boundary layer concept |
| CO.6 | Know methodologies to analyse, design and test wind turbine rotors. |

**CO-PO Mapping:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 2 | 1 | 1 | 1 | |
| **CO.2** | 2 | 1 | 1 | 1 | |
| **CO.3** | 3 | 1 | | 1 | |
| **CO.4** | 3 | 2 | 2 | 1 | 1 |
| **CO.5** | 2 | 1 | 2 | 3 | 1 |
| **CO.6** | 3 | 2 | 3 | 3 | 2 |

**Syllabus:**

Basic equations overview: Continuity, momentum and energy equations. Application of momentum equation. Calculation of drag on two -dimensional body. Inviscid, incompressible flow: Theoretical solutions of potential flow past different bodies. d' Alembert's paradox.

Incompressible flow over aerofoils, aerofoil nomenclature, characteristics, vortex sheet, kutta condition. Kelvin's Circulation Theorem. Classical thin aerofoil theory, Symmetric and cambered aerofoils, Basic aerofoil nomenclature. Prandt's Lifting line Theory. Numerical source panel and vortex panel methods.

Introduction to Viscous Flow, Incompressible Navier-Stokes equations. Boundary layer approximation and separation. Introduction to turbulence and boundary layer transition.

Concepts of blade design: Introduction to rotor design methodologies – low Reynolds Number flows as applied to small wind turbines. Wake formation in wind turbines and its detrimental effects. Similarity rules and introduction to low-speed wind tunnel testing.

***Skill development and Employability:*** *Understand and design the aerodynamics of the wind turbine and as well estimate its performance based on the design aspects.*

**TEXT BOOKS/ REFERENCES:**

1. Anderson J.D., "*Fundamentals of Aerodynamics*", Sixth Edition, Mc-Graw Hill, New York, 2016.

2. Wood David, "*Small Wind Turbines Analysis, Design and Application*", Springer Verlag, London, 2011.

3. DNV- Riso, "*Guidelines for Design of Wind Turbines*", Second Edition, Riso National Laboratory, Denmark, 2002.

4. Lysen, E. H., "*Introduction to Wind Energy*", CWD Report 82-1, Consultancy Services Wind Energy Developing Countries, The Netherlands, May 1983.

5. Schilcting H., "*Boundary Layer Theory*", Eighth Edition, Mc-Graw Hill, India, 2017.

**21RE635** **WIND ELECTRIC GENERATORS** **3-0-0-3**

**Course Objectives:**

- Learn principles, characteristics, modelling and performance analysis of different topologies of wind turbine generators
- Familiarize with enabling FRT capability, grid code compliance, MPPT, WT-generator matching, etc.

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understand the principles and characteristics of wind turbines and electric generators |
| CO.2 | Analyze different types of generators used in WTG |
| CO.3 | Understand power quality issues in WTG and remedies |
| CO.4 | Comprehend FRT issues in WTG, enabling FRT capability and grid code compliance |
| CO.5 | Apply the performance improvement technique on WTG using MPPT and WT-generator matching. |

**CO-PO MAPPING:**

| CO-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 2 | | 2 | | 3 |
| **CO.2** | 3 | | 3 | | 3 |
| **CO.3** | 1 | | 2 | | 3 |
| **CO.4** | 2 | | 2 | | 3 |
| **CO.5** | 3 | | 3 | 2 | 3 |

**Syllabus:**

Status of Wind Power Technologies - Wind Turbine Generator Topologies- Wind turbine characteristics and controls.

Induction generator - Squirrel cage and slip ring machines, equivalent circuit, Torque-slip characteristics, Real and reactive power, self-excited and grid connected systems, Generalized model of electrical machines- Clarke's and Park's transformation, modeling in synchronous reference frame. Doubly fed induction generators- Brush type and Brushless types, four quadrant operation, modeling and Control of Doubly-fed Induction Generators for Wind Turbines, Rotor side converter, Grid side converter.

Synchronous generators-Wound type and permanent magnet types, power angle characteristics, Real and reactive power, Salient and Non salient poles; Modeling and control of Full-scale Converter Wind Turbine Generator- Maximum Power Point Tracking for Wind Turbine - Challenges with Wind Power Integration -Grid Code Requirements for Wind Power Integration-

Power quality issues with grid connected wind electric generators; Reactive power compensation; Harmonics; Voltage unbalance; Voltage flicker; Voltage sag; Fault Ride Through Capability-Low/High Voltage Ride Through Capability, Grid Code; Voltage Operating Range, Frequency Operating Range and Frequency Response, Methods to improve performance of WTG- Fault Ride Through Enhancement of VSC -Power Oscillation Damping from VSC. Advances in wind electric generators.

***Skill development and Employability:*** *Familiarize with the modelling and performance analysis of different topologies of wind turbine generators.*

**TEXT BOOKS/ REFERENCES:**


1. Qiuwei Wu, Yuanzhang Sun, "*Modeling and Modern Control of Wind Power*", IEEE press, John Wiley & Sons Ltd, 2018.
2. J.F. Manwell, J.G. McGowan and A.L. Rogers, "*Wind Energy Explained-Theory, Design and Application*", John Wiley and Sons Ltd. Second Edition. 2010.
3. Olimpo Anaya Lara, Nick Jenkins, Janaka Ekanayaka, Phill Cartwright and Mike Hughes, "*Wind Energy Generation-Modeling and Control*", John Wiley and Sons Ltd., 2009.
4. M. Godoy Simoes and Felix A.Farret, "*Renewable Energy Systems-Design and Analysis With Induction Generators Modeling and analysis with induction Generators*", CRC Press, Third Edition 2015.
5. Fernando D.Bianchi, Hernan De Battista and Ricardo J.Mantz, "*Wind Turbine Control Systems-Principles, Modelling and Gain Scheduling*", Springer-Verlag London Ltd., 2007.
6. Joshua Earnest and Tore Wizelius, "*Wind Power Plants and Project Development*", PHI, Second Edition, 2015.
7. D.P. Kothari and S. Umashankar, "*Wind Energy Systems and Applications*", Alpha Science International, 2014.
8. Joshua Earnest, "*Wind Power Technology*", Third Edition, PHI Learning Pvt. Ltd., New Delhi, 2019.

**21RE636 APPLIED COMPUTATIONAL FLUID DYNAMICS 3-0-0-3**

**Course Objectives:**

- Learn concepts of fluid mechanics and heat transfer
- Apply CFD techniques in thermal systems.
- Apply CFD techniques in the modelling of wind power.

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Apply concepts of fluid mechanics and heat transfer |
| CO.2 | Analyze the discretization methods |
| CO.3 | Analyze different schemes in finite element methods |
| CO.4 | Evaluate thermal systems using CFD techniques |
| CO.5 | Apply CFD techniques in wind power modeling |

**CO-PO Mapping:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 2 | | | | |
| **CO.2** | 2 | 1 | 1 | | |
| **CO.3** | 2 | 1 | 2 | | 1 |
| **CO.4** | 2 | 1 | 1 | 2 | |
| **CO.5** | 2 | 1 | | 2 | |

**Syllabus:**

Introduction to Computational Fluid Dynamics and Principles of Conservation: Models of fluid flow, Governing equations, continuity equation, momentum equation, Initial and boundary conditions. Discretization: Introduction to finite differences, Differences equation, Forward, backward and central difference schemes; explicit and implicit methods. Errors and Analysis of stability, Upwind schemes. Finite volume analysis. CFD Techniques: Lax-Wendroff technique, Mac Cormack's technique. Alternating direction implicit technique. Pressure correction technique: Philosophy of pressure correction method, pressure correction formulae, SIMPLE algorithm. Application: Design optimization of turbine blade profile, CFD Modeling of wind farms (any one technique). Fluid flow analysis using ANSYS.

***Skill development and Employability:*** *Apply CFD techniques in the modelling of wind power.*

**TEXT BOOKS/ REFERENCES:**

1. Versteeg, H.K., and Malalasekara, W, “An Introduction to Computational Fluid Dynamics”, The Finite Volume Method, 2007.

2. Moukalled, F., Mangani, L., & Darwish, M. “The finite volume method in computational fluid dynamics. An Advanced Introduction with OpenFOAM and Matlab”, 2016.

3. Computational Fluid Dynamics: An Introduction. Germany: Springer, 2010.

4. Joel H. Ferziger and MilovanPeric, “*Computational Methods for Fluid Dynamics*”, Springer, 2001.

5. K. Muralidhar and T. Sundararajan, “*Computational Fluid Flow and Heat Transfer*”, Alpha Science International Limited, 2005.

6. Patankar S. “Numerical Heat Transfer and Fluid Flow”. United Kingdom: CRC Press, 2018.

7. Montlaur, Adeline. “Recent Advances in CFD for Wind and Tidal Offshore Turbines” Germany: Springer International Publishing, 2019.

**21RE637** **ENERGY STORAGE SYSTEMS** **3-0-0-3**

**Course Objectives:**

- Familiarize with various energy storage systems
- Design and model different types of energy storage systems for RE applications
- Evaluate performance of various storage systems in various applications.

**Course Outcome (CO)**

| | |
|---|---|
| CO.1 | Understand various chemical, electrical, mechanical storages devices. |
| CO.2 | Evaluate the performance of storage systems for smart energy management |
| CO.3 | Analyse optimal regimes and suitable integration of energy storage systems |
| CO.4 | Design energy storage systems for various applications |

**CO-PO MAPPING:**

| CO- POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 1 | | 1 | | |
| **CO.2** | 3 | | 2 | 1 | 1 |
| **CO.3** | 3 | | 3 | 1 | 1 |
| **CO.4** | 3 | | 3 | 2 | 1 |

**Syllabus:**

Introduction: Necessity of energy storage, different types of energy storage, Mechanical Energy Storage, Pumped Hydro Storage, Electromagnetic Energy Storage, Capacitor and Magnetic Systems, Super Conducting Magnetic Energy Storage, Electrochemical Energy Storage, comparison of energy storage technologies.

Smart Energy Management – High Current Density Battery charging techniques with Battery management system, Hybrid charging techniques in Electric vehicles, Hydrogen and synthetic fuels, Fuel Cells, Consideration on the choice of Energy Storage Systems, Integration of Energy Storage Systems, Optimizing Regimes for Energy Storage in Power Systems, Distributed energy storage with grid interface. Small scale application-Portable storage systems and medical devices, Mobile storage Applications, Hybrid systems for energy storage.

***Skill development and Employability:*** *Design and energy management of energy storage systems for renewable energy and small-scale applications using simulation tools.*

**TEXT BOOKS/ REFERENCES:**

1. Robert A. Huggins, "*Energy Storage*", Springer New York Heidelberg Dordrecht London, 2010.

2. A. Ter-Gazarian, "*Energy Storage for Power Systems*", IET Energy Series 6, London, 2008.

3. Richard Baxter, "*Energy Storage – A Non-Technical Guide*", Penn Well, Oklahoma, 2006. 4. Ralph Zit, "*Energy Storage- A New Approach*", Wiley – Scrivener, Wiley Publishers, 2010.

5. Ahmed Faheem Zobaa, "*Energy Storage – Technologies and Applications*", In Tech Publisher, 2013.

6. C. D. Rahn and C. Wang, "*Battery Systems Engineering*", Wiley Pub, February 2013.

**21RE638** **SMART GRID** **2-1-0-3**

**Course Objectives:**

- To be aware of the significance and requirements of smart grid
- To familiarize with communication technologies and real time monitoring schemes
- To learn phasor and frequency estimation
- To familiarize with standards and regulations for smart grid
- To design smart solutions for power systems

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understand the background of evolution of Smart Grid (SG) |
| CO.2 | Comprehend communication technologies and real time monitoring schemes of SG |
| CO.3 | Analyse energy storage and its management on SG |
| CO.4 | Apply performance analysis tools for SG |
| CO.5 | Understand the standards and regulations for SG infrastructure |

**CO-PO MAPPING:**

| CO-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 1 | | 2 | | |
| **CO.2** | 3 | | 2 | 2 | 3 |
| **CO.3** | 3 | | 2 | 2 | 3 |
| **CO.4** | 3 | | 2 | | 2 |
| **CO.5** | 2 | | 1 | 2 | 2 |

**Syllabus:**

Smart Grid definition, Smart Grid vs conventional grid, Smart Grid technologies -Power system and ICT in Generation, Transmission and Distribution. Basic understanding of power systems. Evolution of power electronics in power system applications, Smart Grid features (Distributed generation, energy storage, Demand Dispatch, Demand Response, Advanced Metering Infrastructure, Wide Area Monitoring System, Wide Area Control System. Sensors - CT, PT, Devices – Intelligent Electronic Device, Phasor Measurement Unit, Phasor Data Concentrator, relays, Demand Response Switch. Communication- Standards, Technology and protocols. Energy management on smart grid – Energy Management System, Dynamic energy storage management, Real time monitoring systems, concepts of cloud and IoT. IoT applications in power system –

IoT on microgrids; IoT for RE generation control, load management, dynamic pricing etc; IoT for domestic prosumers. EV charging and V2G from smart grid.

***Skill development and Employability****: Design smart solutions for power systems using domain specific software.*

**TEXT BOOKS / REFERENCES:**

1. James Momoh, “*Smart Grid: Fundamentals of Design and Analysis*”, Wiley-IEEE Press, March 2012.

2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu and Akihiko Yokoyama, “*SmartGrid: Technology and Applications*”, Wiley, February 2012.

3. NouredineHadjsaïd and Jean-Claude Sabonnadière, “*Smart Grids*”, Wiley-ISTE, May 2012. 4. Ali Keyhani and Muhammad Marwali, “*Smart Power Grids 2011*”, Springer, 2011.

5. Mini S. Thomas, John Douglas McDonald,"*Power System SCADA and Smart Grids*",CRC Press, April 2015.

6. Vijay Madisetti and Arshdeep Bahga, “*Internet of Things: A Hands-on Approach*”, Hardcover – Import, 2014.

**21RE639** **ELECTROCHEMICAL ENERGY SYSTEMS** **3-0-0-3**

**Course Objectives:**

- Learn the functionality, operation and standards involved in various electrochemical devices used in support of renewable energy.

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understand the background of electrode potential and emf generation |
| CO.2 | Evaluate operation of primary and secondary batteries |
| CO.3 | Understand the operation, different types and working principle of fuel cell |
| CO.4 | Comprehend international standards and analyse the performance characteristics of electrochemical devices |

| CO-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 1 | | | | |
| **CO.2** | 2 | 1 | 2 | 2 | 2 |
| **CO.3** | 1 | | | 1 | 1 |
| **CO.4** | 2 | 1 | 2 | 2 | 2 |

**Syllabus:**

**Fundamentals of electrochemistry**: Quantitative Electrochemistry-Faradays laws and its applications, Thermodynamics of electrochemical reactions, Origin of potential –electrical double layer – reversible electrode potential-emf series- Nernst equation – Kinetics of electrochemical reactions-Butler-Volmer equation - Activation, concentration and IR overpotentials - Tafel plots and its applications

**Primary and secondary batteries**: The chemistry, fabrication and performance aspects, packing classification and rating of zinc and lithium primary batteries, Lead acid, nickel, silver and lithium-ion secondary batteries- Lithium polymer batteries, VRLA batteries-Sodium-beta and Redox batteries for vehicles - Thermally activated reserve batteries.

**Fuel Cells**: Working principle, fabrication of electrodes and other components, and environmental aspects of Proton Exchange Membrane Fuel Cells, Alkaline fuel cells, Phosphoric acid, Solid oxide, Molten carbonate, Direct methanol fuel cells - Reformation clean up and storage for hydrogen

**Testing and Assessment of Batteries** - Shelf life and service life– effect of temperature and pressure – effect of aging –memory effect – test conditions, mechanical and environmental, load and electromagnetic compatibility testing. Selected international standards – performance characteristics –Peuckert discharge curves, Ragone plots, Supercapacitors, EDLC, Pseudo and hybrid capacitors.

Introduction to types of batteries using for grid support. Li-ion battery circular economy

***Skill development and Employability:*** *Develop the knowledge in the construction, the reactions involved and the evaluation of performance of different types of industrial energy storage devices in the field of automobile batteries, fuel cells, renewable energy and consumer electronics industries.*

**TEXT BOOKS/ REFERENCES:**


1.Dell, Ronald M Rand and David AJ, "*Understanding Batteries*", Royal Society of Chemistry, 2001.

2.M. AuliceScibioh and B. Viswanathan, "*Fuel Cells – Principles and Applications*", University Press, India, 2006.

3.F. Barbir, "*PEM Fuel Cells: Theory and Practice*", Elsevier, Burlington, MA, 2005.

4. David Linden and Thomas B Reddy, "*Handbook of Batteries*", Fourth Edition, McGraw-Hill, 2011

5.Derek Pletcher and Frank C. Walsh, "*Industrial Electrochemistry*", Blackie Academic and Professional, 1993.

**21RE640** **PROJECT MANAGEMENT** **3-0-0-3**

**Course Objectives:**

- To understand the project operations system.
- To introduce the project scheduling software like MS Project. Handle project execution tools and techniques, recognize various project network problems and solve.
- Study operational issues of project organizations.

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understand the differences between past and present methods of managing projects. |
| CO.2 | Identify and recommend the determinants of effective and efficient use of an operations system. |
| CO.3 | Apply project execution tools and techniques. |
| CO.4 | Solve various kinds of project network problems using appropriate quantitative analytical tools. |
| CO.5 | Analyse and evaluate operational issues of project organizations. |

**CO-PO Mapping:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 1 | | 1 | 2 | 1 |
| **CO.2** | 3 | | 3 | 2 | 1 |
| **CO.3** | 3 | | 3 | 2 | 2 |
| **CO.4** | 3 | | 3 | 2 | 2 |
| **CO.5** | 3 | | 3 | 2 | 2 |

**Syllabus:**

Project Life Cycle Concept; Nature of Project Management: An overview of Project Management. Scope Management. Project Selection. PM tools & techniques: using MS Project: a) Time b) Resources, c) Cost, d) Updating. Project Feasibility. Project Appraisal. Work Breakdown Structure, Project Accounts. Project Design: Detailed Project Report.

Project Execution: Procurement, Project Control, Earned Value Construction Resource Plan, Engineering Management, Site Management, Project Reviews Role of Agencies. Behavioural aspects of PM: PM Organization, Project Teams, Project leadership. Project Quality Management. Project Management Information System. Project Risk Management. Project Termination. Project Evaluation. PM Case Study.

***Skill development and Employability:*** *Handle project execution tools and techniques, recognize various project network problems and solve, and, study operational issues of project organizations.*

**TEXT BOOKS/ REFERENCES:**

1. Burke, Rory, "*Project management: planning and control techniques*", Wiley, India, 2016.

2. Meredith, Jack R, Samuel J and Mantel Jr., "*Project Management- A Managerial Approach*", 10th Edition, John Wiley, 2017.

2.Klastorin Ted, "*Project Management, Tools, and Trade-offs*", John Wiley, 2004.

3.Mantel, Meredith, Shafer and Sutton A, "*Core Concepts of Project Management*", John Wiley, 2001.

4. Larson, E. W., & Gray, C. F., "Project Management: The Managerial Process", Sixth Edition, Tata McGraw-Hill Education., 2017.

**21RE641 ENERGY FORECASTING AND MODELING 3-0-0-3**

**Course Objectives:**

- Develop energy system models for short term and long term forecasting
- Develop energy optimization models for different scenarios and use in energy

**Course Outcome(CO):**

| | |
|---|---|
| CO.1 | Understand the scenario of energy management and forecasting relevant to climatic change mitigation. |
| CO.2 | Develop different energy system models for short term and long-term forecasting. |
| CO.3 | Quantify the sensitivity of different energy system models according to forecast accuracy |
| CO.4 | Apply various optimization techniques and development of energy optimization models for different scenarios |
| CO.5 | Simulate various energy forecasting models with different optimization methods. |

**CO-PO MAPPING:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 2 | | 1 | 1 | 1 |
| **CO.2** | 3 | | 2 | 1 | 1 |
| **CO.3** | 2 | | 2 | 1 | 1 |
| **CO.4** | 3 | | 2 | 3 | 3 |
| **CO.5** | 2 | | 3 | 3 | 3 |

**Syllabus:**

Energy Scenario: Role of energy in economic development and social transformation: Energy & GDP, GNP and its dynamics-Energy Sources and Overall Energy demand and Availability-Energy Consumption in various sectors and its changing pattern-Status of Nuclear and Renewable Energy: Present Status and future promise.

Forecasting Model: Forecasting Techniques-Regression Analysis-Double Moving Average-Double Experimental Smoothing-Triple Exponential Smoothing– ARIMA model-Validation techniques–Qualitative forecasting–Delphi technique-Concept of Neural Net Works.

Optimization Model: Principles of Optimization-Formulation of Objective Function -Constraints-Multi Objective Optimization–Mathematical Optimization Software–Development of Energy Optimization Model -Development of Scenarios– Sensitivity Analysis. Wind energy prediction and forecasting using Python programming.

***Skill developments and Employability:*** *Develop energy optimization models for different scenarios and use in energy sectors.*

**TEXT BOOKS / REFERENCES:**

1.S. Makridakis, "*Forecasting Methods and Applications*", Wiley 1983.

2. Yang X.S., "*Introduction to Mathematical Optimization: From Linear Programming to Metaheuristics*", Cambridge, Int. Science Publishing. Fith edition. 2008.

3. Armstrong, J.Scott (ed.),"*Principles of Forecasting: A Hand Book for Researchers and Practitioners*", Norwell, Masschusetts: Kluwer Academic Publishers, 2001.

**21RE642** **OCEAN ENERGY CONVERSION** **3-0-0-3**

**Course Objectives:**

- Recapitulate concepts of thermodynamics and apply in refrigeration cycles.
- Learn ocean thermal, tidal and wave energy conversion technologies and the performance evaluation
- Study ocean bio-energy resources and ocean geothermal energy

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Apply concepts of thermodynamics in power and refrigeration cycles |
| CO.2 | Understand ocean energy resources |
| CO.3 | Analyse and evaluate ocean thermal energy conversion methods |
| CO.4 | Analyse the tidal energy conversion systems |
| CO.5 | Analyse and compare various ocean wave energy converters |
| CO.6 | Evaluate the ocean bio-energy resources and ocean geothermal energy |

**CO-PO Mapping:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 3 | | 2 | | 2 |
| **CO.2** | 3 | | | | |
| **CO.3** | 3 | | 2 | 1 | 1 |
| **CO.4** | 3 | | 2 | 1 | 1 |
| **CO.5** | 3 | 2 | 2 | 1 | |
| **CO.6** | 3 | 2 | 2 | 1 | 1 |

**Syllabus:**

Ocean Energy – Environmental impacts of ocean energy utilization – Ocean energy routes; Ocean Thermal Energy Conversion – Open and closed cycles for operation – Efficiencies of OTEC plants and their influence on plant size – Cogeneration of electricity and fresh water from open cycle OTEC; Tidal Energy –Origin of tides – Single basin and Double basin systems – Tidal plants in India and around the world in operation; Wave energy – Parameters of progressive wave – Equation of wave – Energy and power in ocean waves - Types of wave energy convertors – Dolphin-Buoy type, Oscillating float-air pump type, three-raft type converters; Ocean biomass energy – Principal marine bio-energy resources – Kelp bio-energy conversion process; Ocean Geothermal Energy – Availability and limitations – Conversion methods.

***Skill development and Employability:*** *Study of ocean bio-energy resources and ocean geothermal energy.*

**TEXTBOOKS/ REFERENCES:**


1. Zabihian Farshid. “Power Plant Engineering”.: CRC Press, 2021.
2. Kreith Frank. “Energy Conversion”. United States: CRC Press, 2017.
3. RH Charlier, Charles W Finkl, “*Ocean Energy: Tide and Tidal Power*”, Springer, 2010.
4. Neill Simon P., Hashemi M Reza. “Fundamentals of Ocean Renewable Energy: Generating Electricity from the Sea.” United Kingdom: Elsevier Science, 2018.
5. Kofoed Jens Peter. “Handbook of Ocean Wave Energy.” Germany: Springer International Publishing, 2016.
6. Babarit Aurelien, “*Ocean Wave Energy Conversion: Resource, Technologies and Performance*”, Netherlands, Elsevier Science, 2017.

**21RE643 COMPUTATIONAL OPTIMIZATION THEORY – LINEAR AND NON-LINEAR METHODS** **3-0-0-3**

**Course Objectives:**

- Learn linear and non-linear optimization methods
- Solve engineering problems by applying linear and non-linear optimization

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understand the different types of Optimization Techniques in engineering problems. |
| CO.2 | Understand gradient based Optimizations Techniques in single variables as well as multivariable (non-linear). |
| CO.3 | Apply linear programming, transportation problems and interior point methods on real world problems |
| CO.4 | Apply engineering problems by applying Linear and Non- Linear optimization techniques |

**CO-PO MAPPING:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 1 | | | | |
| **CO.2** | 1 | | | 1 | 1 |
| **CO.3** | 2 | 1 | 1 | 2 | 2 |
| **CO.4** | 2 | 1 | 1 | 2 | 2 |

**Syllabus:**

Introduction and basic concepts – Classification of optimization problems, Objective function; Constraints and Constraint surface; Formulation of problems as mathematical programming problems.

Linear Programming - Introduction to linear programming model, Simplex method, Duality, Karmarkar's method. Geometry of Linear programming problems, Simplex methods, Duality in Linear programming, Markov Chain Monte Carlo Methods, Dynamic Programming.

Single and Multivariable Optimization for unconstrained optimization - Optimality criteria, Gradient based methods - Steepest descent, Conjugate direction, Conjugate gradient, Newton's, Levenberg Marquardt, Quasi Newton, Variable metric and BFGS method.

Constrained Optimization - Direct methods – Frank-Wolfe method, Cutting plane method, Method of feasible direction - Gradient projection method, Indirect methods -Transformation techniques, Penalty function methods for mixed equality and inequality constraints.

Non-linear problems- Non-linear constrained optimization models, Karush-Kuhn-Tucker optimality criteria, Projection methods, Interior Point methods.

***Skill development and Employability:*** *Solve engineering problems by applying linear and non-linear optimization.*

**TEXT BOOKS/ REFERENCES:**

1. S. S. Rao, "*Optimization Theory and Practice*", Fifth Edition, John Wiley and Sons.2019

2. Kalyanmoy Deb, "*Optimization for Engineering Design Algorithms and Examples*", Prentice Hall of India, New Delhi, 2004.

3. Edwin K.P. Chong and Stanislaw H. Zak, "An Introduction to *Optimization*", Fourth Edition, Wiley-Interscience Series in Discrete Mathematics and Optimization, 2017.

4. M. AsgharBhatti, "*Practical Optimization Methods: with Mathematical Applications*", Springer Verlag Publishers, 2000.

5. Mykel J. Kochenderfer and Tim A. Wheeler, "Algorithms for Optimization", The MIT Press, 2019.

**21RE644** **ELECTRICTY MARKET** **3 0 0 3**

**Course Objectives:**

- To provide knowledge on the structure of electricity market.
- To understand the concepts of power trading.

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understand the economics of power market. |
| CO.2 | Understand the functioning of various electricity markets. |
| CO.3 | Analyse the power trading and market settlement. |
| CO.4 | Apply suitable market management technique to handle congestion in power system |
| CO.5 | Analyse ancillary services in the power market. |

**CO-PO Mapping:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 2 | | 1 | | |
| **CO.2** | 2 | | 2 | | |
| **CO.3** | 2 | | 3 | 2 | 2 |
| **CO.4** | 2 | | 3 | 2 | 2 |
| **CO.5** | 2 | | 3 | 2 | 2 |

**Syllabus:**

Introduction to the Electric Power Grid ; Basics of Electric Power Flow, Economics of Power Generation, Transmission and Distribution; Economic Dispatch of Power plants; Consumer and supplier behaviour, market equilibrium ; Power market regulations -Open Access in inter-state transmission Regulations

The Philosophy of Market Models-Monopoly, wholesale, retail competition models; Bilateral, spot market, Auctioning; Day ahead and real time energy Market; Power exchange platforms.

Transmission Congestion Management -ATC calculation; Locational Marginal Prices (LMP) and, Financial Transmission Rights (FTR).

Ancillary Service Management. -Frequency regulation; Voltage control and reactive power support services; Black start capability service; Co-optimization of energy and reserve services; Ancillary service market

Pricing of transmission network usage and loss allocation-Power wheeling; Zonal pricing; Marginal transmission pricing; loss allocation methods - Pro-rata methods. Incremental methods, Power flow tracing-based allocation.

US and European market evolution. Reforms in Indian power sector.

***Skill development and Employability:*** *Analyse the market model and its mechanism in electricity market.*

**TEXT BOOKS/ REFERENCES:**


1. Daniel Kirschen and Goran Strbac, "*Fundamentals of Power System economics*", John Wiley & Sons Ltd, 2$^{nd}$ Edition, 2018.
2. Sally Hunt, "*Making competition work in electricity*", John Wiley & Sons, Inc., 2002.
3. Kankar Bhattacharya, Jaap E. Daadler, Math H.J Bollen, "*Operation of restructured power systems*", Kluwer Academic Pub., 2001.

**21RE645** **GREEN BUILDING AND TECHNOLOGIES** **3-0-0-3**

**Course Objectives:**

- To provide knowledge on the green building and its requirement towards energy efficiency.
- To understand the materials and ratings of the green building infrastructure.

**Course Outcome(CO)**

| | |
|---|---|
| CO.1 | Understand the features and green building infrastructure and its standards |
| CO.2 | Perform site selection, planning, water conservation and efficiency |
| CO.3 | Analyse the energy efficiency and its methods in green building. |
| CO.4 | Comprehend suitable building material and perform waste management |
| CO.5 | Understand indoor environmental quality and the codes followed for green building initiative |

**CO-PO Mapping:**

| COs-POs | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|
| **CO.1** | 2 | | 1 | 1 | |
| **CO.2** | 2 | | 2 | 2 | 1 |
| **CO.3** | 2 | | 3 | 2 | 1 |
| **CO.4** | 2 | | 3 | 2 | 2 |
| **CO.5** | 2 | | 1 | 2 | |

**Syllabus:**

Introduction to Green Buildings: Definition of green buildings and sustainable development, typical features of green buildings, benefits of green buildings towards sustainable development. Green building rating systems – GRIHA, IGBC and LEED, overview of the criteria as per these rating systems. Site selection and planning: Criteria for site selection, preservation of landscape, soil erosion control, minimizing urban heat island effect, maximize comfort by proper orientation of building facades, day lighting, ventilation.

Water conservation and efficiency: Rainwater harvesting methods for roof & non-roof, reducing landscape water demand by proper irrigation systems, water efficient plumbing systems, water metering, waste water treatment, recycle and reuse systems.

Energy Efficiency: Environmental impact of building constructions, Concepts of embodied energy, operational energy and life cycle energy. Methods to reduce operational energy: Energy efficient building envelopes, efficient lighting technologies, energy efficient appliances for heating and air-conditioning systems in buildings, zero ozone depleting potential (ODP) materials, wind and solar energy harvesting, energy metering and monitoring, concept of net zero buildings.

Building materials: Methods to reduce embodied energy in building materials: (a) Use of local building materials (b) Use of natural and renewable materials like bamboo, timber, rammed earth, stabilized mud blocks, (c) use of materials with recycled content such as blended cements, pozzolana cements, fly ash bricks, vitrified tiles, materials from agro and industrial waste. (d) reuse of waste and salvaged materials

Waste Management: Handling of construction waste materials, separation of household waste, on-site and off-site organic waste management.

Indoor Environmental Quality for Occupant Comfort and Wellbeing: Daylighting, air ventilation, exhaust systems, low VOC paints, materials & adhesives, building acoustics. Codes related to green buildings: NBC, ECBC, ASHRAE, UPC.

***Skill development /Employability:*** *Design appropriate green building with the materials, water conservation, waste management, quality measures using energy efficient technologies.*

**TEXT BOOKS/ REFERENCES:**

1. IGBC Green Homes Rating System, Version 3.0., Abridged reference guide, Indian Green Building Council Publishers, 2019.

2. GRIHA version 2015, GRIHA rating system, Green Rating for Integrated Habitat Assessment.

3. K.S. Jagadish, B.V. Venkatarama Reddy and K.S. Nanjunda Rao, "Alternative building materials and technologies", New Age International Publishers, 2017.

4.G.D. Rai, "*Non-Conventional Energy Resources*", Khanna Publishers.5. Sustainable Building Design Manual, Vol.1 and 2, TERI, New Delhi 2004.

6. Mike Montoya, Green Building Fundamentals, Pearson, 2$^{nd}$ Edition, USA, 2011.

7. Charles J. Kibert, Sustainable Construction – Green Building Design and Delivery, John Wiley & Sons, New York, 4$^{th}$ Edition, 2016.

8. Regina Leffers, Sustainable Construction and Design, Pearson / Prentice Hall, USA, 2009.

**21RE798/ 21RE799 DISSERTATION 10/16**

**Course Objectives:**

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

**Course Outcomes (CO)**

| | | |
|---|---|---|
| 21RE798 Dissertation | CO.1 | Understand research methodology |
| | CO.2 | Plan and execute Projects |
| | CO.3 | Survey and review literature |
| | CO.4 | Choose computational and analytical tools and design experiments |
| | CO.5 | Communicate technical content orally as well as in writing with added skill |
| 21RE799 Dissertation | CO.1 | Plan and manage projects with skill |
| | CO.2 | Analyse results and acquire domain knowledge |
| | CO.3 | Use computational and analytical tools with skill |
| | CO.4 | Demonstrate skill in technical communication |
| | CO.5 | Comprehend and disseminate knowledge |

CO-PO MAPPING 21RE798:

| CO-POs | CO Statement | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|---|
| **CO.1** | Understanding research methodology | 3 | 2 | | | |
| **CO.2** | Plan and execute Projects | 3 | 2 | | | |
| **CO.3** | Survey and review literature | 3 | 3 | | | |
| **CO.4** | Choose computational and analytical tools and design experiments | 3 | 2 | 1 | 1 | 3 |
| **CO.5** | Communicate technical content orally as well as in writing with added skill | 2 | 3 | | 1 | 1 |

CO-PO MAPPING 21RE799:

| CO-POs | CO Statement | PO1 | PO2 | PO3 | PO4 | PO5 |
|---|---|---|---|---|---|---|
| **CO.1** | Plan and manage projects with skill | 3 | 2 | | | |
| **CO.2** | Analyze results and acquire domain knowledge | 3 | 2 | 3 | 3 | 3 |
| **CO.3** | Use computational and analytical tools with skill | 3 | 2 | 3 | 3 | 2 |
| **CO.4** | Demonstrate skill in technical communication | 3 | 3 | | 1 | 1 |
| **CO.5** | Comprehend and disseminate knowledge | 3 | 3 | 3 | 2 | 2 |

Each student should select and work on a topic related to his/her field of specialization during summer of second semester under the supervision of a faculty member. During third and fourth semester each student should work on the selected topic under the supervision of a faculty member. By the end of each (third and fourth) semester the student has to prepare a report in the approved format and present it.