THE VISION OF THE DEPARTMENT OF MECHANICAL ENGINEERING

The Department of Mechanical Engineering strives to be recognized globally for excelling in engineering education and research leading to innovative, entrepreneurial and competent graduates in Mechanical Engineering and allied disciplines.

THE MISSION OF THE DEPARTMENT OF MECHANICAL ENGINEERING

- Providing world class education by fostering effective teaching learning process that is supported through pioneering and cutting-edge research to make impactful contribution to the society.

- Attracting highly motivated students with enthusiasm, aptitude and interest in the field of Mechanical and allied Engineering disciplines.

- Expanding the frontiers of Engineering and science in technological innovation while ensuring academic excellence and scholarly learning in a collegial environment.

- Excelling in industrial consultancy and research leading to innovative technology development and transfer.

- Serving the society with Innovative and entrepreneurially competent graduates for the national and international community towards achieving the sustainable development goals.
PROGRAMME EDUCATIONAL OBJECTIVES (PEOs):

The Solar Energy program seeks to prepare PG students for productive and rewarding careers in the solar energy arena. The PEOs are listed below:

- (i) Acquire knowledge and employability in solar energy sector with requisite skills facilitating quick progress in graduands career
- (ii) Inclination towards advanced research for mitigating the shortcomings in solar energy systems.
- (iii) Ascending as an solar energy consultant/entrepreneur for providing solutions towards improving the efficacy of energy systems.
- (iv) Lead an ethical life by engaging in lifelong learning experiences for developing environmentally sustainable and economically affordable solar energy products for societal upliftment.

PROGRAMME OUTCOMES (POs):

- (i) An ability to independently carry out research/investigation and development work to solve practical problems
- (ii) An ability to write and present a substantial technical report/document
- (iii) Students should be able to demonstrate a degree of mastery over the area as per the specialization of the programme.
- (iv) Expertise to use various simulation software related to solar energy systems to identify research gaps and ideate innovations
- (v) Design and optimize solar energy systems with environmental consciousness for sustainable development.
- (vi) Awareness on Solar Energy policy and scenario at state, national and global level.

PEO - PO Mapping:

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ANNA UNIVERSITY, CHENNAI
UNIVERSITY DEPARTMENTS
REGULATIONS - 2023
CHOICE BASED CREDIT SYSTEM
CURRICULUM AND SYLLABI FOR SEMESTER I TO IV
M.E. SOLAR ENERGY

**SEMESTER I**

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* (a) To be carried out in a solar energy related industry during the 2nd semester vacation
(b) Minimum period of training = 4 weeks
(c) Evaluation to be carried out on the first week of 3rd semester
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Total credits for the programme = 26 + 19 + 15 + 12 = 72

**Students are permitted to**

(i) **Study any 2 courses - equivalent to the subjects mentioned in the curriculum - in National Programme on Technology Enhanced Learning (NPTEL), Govt. of India** AND/OR

(ii) **Study any 2 TECHNICAL courses for consideration under Program Electives amongst the core/elective courses offered in the University Departments**

Prior approval of (1) Faculty Adviser, (2) Professor–i/c of PG Programme, (3) HoD – Dept. of Mech. Engg., and (4) Chairperson – Faculty of Mechanical Engineering is to be obtained for the above.
### FOUNDATION COURSES (FC)

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## Summary

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OBJECTIVES:

- To impart knowledge in understanding the advantages of various solution procedures of solving the system of linear and nonlinear equations.
- To give a clear picture about the solution methods for solving the BVPs and the system of IVPs.
- To acquire knowledge in solving time dependent one and two dimensional parabolic PDEs by using various methodologies.
- To strengthen the knowledge of finite difference methods for solving elliptic equations.
- To get exposed to the ideas of solving PDEs by finite element method.

UNIT I  ALGEBRAIC EQUATIONS  

UNIT II  ORDINARY DIFFERENTIAL EQUATIONS  
Runge Kutta Methods for system of IVPs, numerical stability, Adams-Bashforth multistep method, solution of stiff ODEs, shooting method, BVP: Finite difference method, collocation method, orthogonal collocation method, Galerkin finite element method.

UNIT III  FINITE DIFFERENCE METHOD FOR TIME DEPENDENT PARTIAL DIFFERENTIAL EQUATION  

UNIT IV  FINITE DIFFERENCE METHODS FOR ELLIPTIC EQUATIONS  
Laplace and Poisson’s equations in a rectangular region: Five point finite difference schemes, Leibmann’s iterative methods, Dirichlet and Neumann conditions – Laplace equation in polar coordinates: finite difference schemes – approximation of derivatives near a curved boundary while using a square mesh.

UNIT V  FINITE ELEMENT METHOD  

TOTAL: 60 PERIODS

OUTCOMES:
At the end of the course, students will be able to
CO1 Get familiarized with the methods which are required for solving system of linear, nonlinear equations and eigenvalue problems.
CO2 Solve the BVPs and the system of IVPs by appropriate methods discussed.
CO3 Solve time dependent parabolic PDEs by using various methodologies up to dimension two.
CO4 Solve elliptic equations by finite difference methods.
CO5 Use the ideas of solving PDEs by finite element method.
REFERENCES:

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OBJECTIVE:
The major objective of this course is to introduce the advanced thermodynamic concepts which are useful in understanding fundamental concepts of availability, entropy generation, properties of matter and to apply in various Engineering problems involving energy transfer, chemical processing, etc. The course will focus on both energy producing and consuming thermodynamic cycle’s system energy and exergy analysis.

UNIT – I  FUNDAMENTAL LAWS, CLOSED and OPEN SYSTEMS  12
Zeroth, First and Second law of Thermodynamics, Fundamental equations for closed systems, Process, Relations, Second law efficiency for a closed system, Fundamental equations for open systems, Steady state operations, Flow in channel, turbine and compressors

UNIT – II  ENTROPY GENERATION  12

UNIT – III  THERMODYNAMIC PROPERTIES of MATTER  12

UNIT – IV  THERMODYNAMIC CYCLES  12

UNIT – V  ENERGY and EXERGY ANALYSIS  12

TOTAL: 60 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:
CO 1  Understand the thermodynamic system, and apply various thermodynamic relations
CO 2  Analyze the entropy generation in various processes
CO 3  Predict the behavior of real gas and calculate the properties of gas mixtures
CO 4  Apply various thermodynamic cycles for various work producing and consuming systems
CO 5  Apply the thermodynamic knowledge for analyzing the energy and exergy concepts in different applications.
REFERENCES
3. Kuo, K.K., Principles of Combustion, John Wiley and Sons, 2005

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OBJECTIVE:
The main objective of the course is to impart knowledge to students on the concepts of fluid kinematics, boundary layer theory, incompressible and compressible fluid flow analysis. The course is also useful to enhance the student knowledge on various modes of heat transfer and the applications of heat transfer.

UNIT – I  FLUID KINEMATICS AND BOUNDARY LAYER THEORY  12

UNIT – II  INCOMPRESSIBLE AND COMPRESSIBLE FLOWS  12

UNIT – III  CONDUCTION AND CONVECTION HEAT TRANSFER  12

UNIT – IV  RADIATION HEAT TRANSFER  12
Surface radiation – View factor analysis, Gas Radiation - Radiative Transfer Equation (RTE), Radiation properties of a participating medium, Use of Hottel’s Graph, Correction factor analysis - Inverse problems in radiation transfer.

UNIT – V  HEAT EXCHANGER AND HEAT PIPE  12

OUTCOMES:
Upon completion of this course, the students will be able to:
CO 1  Identify, formulate, and analyze the governing equations for various engineering applications.
CO 2  Learn the flow concepts of incompressible and compressible flow.
CO 3  Solve the conduction and convection heat transfer problems.
CO 4  Understand the importance of radiation heat transfer in gases and inverse solution methods.
CO 5  Design a heat exchanger and heat pipe as per the industrial needs.
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OBJECTIVE:
Acquaintance with the Indian and Global energy scenario and to edify on the potential and prospects of various renewable energy technologies.

UNIT – I  ENERGY AND ENVIRONMENT  9L

UNIT – II  SOLAR ENERGY  9L+15P

UNIT – III  WIND ENERGY  9L+3P

UNIT – IV  BIO-ENERGY  9L+9P
Bio resources – Thermochemical Conversion: combustion, gasification, pyrolysis and carbonisation – Biochemical conversion: Biomethanation, Fermentation – Physiochemical : Biodiesel, Briquetting and Pelletisation – Applications

UNIT – V  HYDRO, GEOTHERMAL & HYBRID ENERGY SYSTEMS  9L+3P
Small hydro - Tidal energy – Wave energy – OTEC – Geothermal energy – Hybrid systems – Environmental impacts

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 Comprehend on the Indian energy scenario
CO2 Design a Solar Thermal / PV system for any requirement
CO3 Estimate the available wind energy in a particular site
CO4 Suggest suitable conversion mechanism for generating power from Biomass
CO5 Elucidate on the technologies for harnessing power from ocean and geothermal energy.

REFERENCES:
Practical

1. Study of Direct and diffused beam solar radiation
2. Performance evaluation of Solar Flat Plate Collector
3. Determining the I-V characteristics of Solar PV panel
4. Performance evaluation of solar cookers (box type and concentrating type)
5. Determining the I-V Characteristics of a Fuel Cell
6. Performance evaluation of a green hydrogen generation and storage system
7. Performance evaluation of wind turbine
8. Performance evaluation of different turbines employed in hydro power plant
9. Study of Biomethanation plant
10. Study of Biomass briquetting plant

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OBJECTIVES:
The major objectives of this course is to impart the knowledge on the basics of solar radiation, solar geometry, solar system components and their significance.

UNIT – I SOLAR RADIATION 9L+12P
Basics of solar energy - Brief History of solar energy utilization - Various approaches of utilizing solar energy - Blackbody radiation - Relation between radiation field energy density and radiation spectrum - Planck’s formula in energy unit - Maximum spectral density - Planck’s formula in wavelength unit - Wien displacement law - Stefan - Boltzmann law – Photoelectric effect - Einstein’s theory of photons - Einstein’s derivation of the black-body formula.

UNIT – II SOLAR GEOMETRY AND AIR MASS 9L
Rotation and orbital motion of the Earth around the Sun - Solar time, sidereal time, universal standard time, local standard time - Equation of time - Intensity of sunlight on an arbitrary surface at any time - Interaction with the atmosphere - Air mass - Rayleigh and Mie scattering - Absorption.

UNIT – III SOLAR CELLS 9L+6P
Formation of a PN – junction - Space charge and internal field - Quasi - Fermi levels – Shockley diode equation - solar cell equation – IV Characteristics- Various electron-hole pair recombination mechanisms –Theoretical efficiency, Internal and external quantum efficiency - Structure of a solar cell – Types of PV cells

UNIT – IV SOLAR THERMAL COLLECTORS 9L+6P

UNIT – V SOLAR ENERGY STORAGE MATERIALS 9L+6P
Necessity of storage for solar energy - Chemical energy storage - Thermal energy storage – Phase change materials storage – Composite phase change materials storage.

TOTAL: 75 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 Enumerate the basic laws related to the solar radiation.
CO2 Predict the solar time due to the motion of the earth with respect to sun.
CO3 Provide accurate diagrams of solar cells and be able to classify solar cells and their working mechanisms.
CO4 Understand the basics of working and testing of solar thermal collectors.
CO5 Understand the need of storage for solar energy and selection of materials for solar energy storage.
REFERENCES:

Practical

1. Solar radiation measurement
2. Study on solar radiation and meteorological data for the given location and mapping daily and monthly averages.
3. Estimation of IV characteristics of a PV cell
4. Performance assessment of solar thermal collectors
5. Characterisation of energy storage materials

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OBJECTIVE:
The primary goal of this course is to enrich the students understanding of different measuring instruments, methodologies, and the significance of error and uncertainty analysis. Additionally, this course will equip students with the skills required to design appropriate control unit for a range of thermal systems.

UNIT – I  BASICS OF MEASUREMENTS
Introduction, general measurement system, Signal flow diagram of measurement system, Inputs and their methods of correction, Presentation of experimental data, Errors in measurement, Propagation of errors, Uncertainty analysis, Regression analysis, Transient response – zeroth, first and second order measurement systems.

UNIT – II  THERMOMETRY AND HEAT FLUX MEASUREMENT
Overview of thermometry, Thermoelectric temperature measurement, Resistance thermometry, Pyrometer, Other methods and Calibration procedure, Challenges in temperature measurements, Principles of Heat flux measurement.

UNIT – III  PRESSURE, FLOW AND THERMAL PROPERTY MEASUREMENT
Different pressure measurement instruments and their comparison, Transient response of pressure transducers, Flow Measurement, Flow obstruction methods, Magnetic flow meters, Interferometer, LDA, Other methods, Thermo-physical property measurement - Steady and Unsteady methods for solids, fluids and PCMs.

UNIT – IV  CONTROL SYSTEMS, COMPONENTS, AND CONTROLLERS
Introduction, Open and closed loop control systems, Transfer function. Types of feedback and feedback control system characteristics – Control system parameters – DC and AC servomotors, servo amplifier, potentiometer, synchro transmitters, synchro receivers, synchro control transformer, stepper motors - Continuous, Discontinuous and Composite control modes – Analog and Digital controllers.

UNIT – V  DESIGN OF MEASUREMENT AND CONTROL SYSTEMS
Data logging and acquisition - Integration of industrial instrumentation systems and monitoring, sensors for error reduction, elements of computer interfacing, timers and counters, designing measurement and control systems for specific applications, fault finding, and computer-based controls.

OUTCOMES:
Upon completion of this course, the students will be able to:

CO1 Understand the concepts of errors in measurements, statistical analysis of data, regression analysis, correlation, and estimation of uncertainty.

CO2 Select appropriate sensors for measurement of specific parameters/properties with required accuracy.

CO3 Carry out calibration and evaluate measurement systems using uncertainty analysis.

CO4 Distinguish between measurement and control systems, and use appropriate control system for an application.

CO5 Construct a complete control system for a thermal application.

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OBJECTIVES:
To impart knowledge on
- Formulation of research problems, design of experiment, collection of data, interpretation and presentation of result
- Intellectual property rights, patenting and licensing

UNIT I  RESEARCH PROBLEM FORMULATION  9
Objectives of research, types of research, research process, approaches to research; conducting literature review- information sources, information retrieval, tools for identifying literature, Indexing and abstracting services, Citation indexes, summarizing the review, critical review, identifying research gap, conceptualizing and hypothesizing the research gap

UNIT II  RESEARCH DESIGN AND DATA COLLECTION  9
Statistical design of experiments- types and principles; data types & classification; data collection - methods and tools

UNIT III  DATA ANALYSIS, INTERPRETATION AND REPORTING  9
Sampling, sampling error, measures of central tendency and variation; test of hypothesis-concepts; data presentation- types of tables and illustrations; guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript; guidelines for writing thesis, research proposal; References – Styles and methods, Citation and listing system of documents; plagiarism, ethical considerations in research

UNIT IV  INTELLECTUAL PROPERTY RIGHTS  9
Concept of IPR, types of IPR – Patent, Designs, Trademarks and Trade secrets, Geographical indications, Copy rights, applicability of these IPR; IPR & biodiversity; IPR development process, role of WIPO and WTO in IPR establishments, common rules of IPR practices, types and features of IPR agreement, functions of UNESCO in IPR maintenance.

UNIT V  PATENTS  9
Patents – objectives and benefits of patent, concept, features of patent, inventive steps, specifications, types of patent application; patenting process - patent filling, examination of patent, grant of patent, revocation; equitable assignments; Licenses, licensing of patents; patent agents, registration of patent agents.

COURSE OUTCOMES
Upon completion of the course, the student can
CO1: Describe different types of research; identify, review and define the research problem
CO2: Select suitable design of experiment s; describe types of data and the tools for collection of data
CO3: Explain the process of data analysis; interpret and present the result in suitable form
CO4: Explain about Intellectual property rights, types and procedures
CO5: Execute patent filing and licensing

TOTAL: 45 PERIODS

REFERENCES:
2. Soumitro Banerjee, “Research methodology for natural sciences”, IISc Press, Kolkata, 2022,
OBJECTIVES:
The objective of this course is to provide in-depth understanding to students on solar photovoltaic systems, design of various PV interconnected systems, grid connected PV systems and hybrid systems. This course will also enable students to design the system components for different PV Applications.

UNIT – I  SOLAR PV MODULES  9L+8P

UNIT – II  STAND ALONE PV SYSTEMS  9L+10P
Schematics and Components - Balance of system components for DC and/or AC Applications - Maximum power point tracking (MPPT) algorithms - Interfacing PV modules to loads - Connection of PV modules to a battery and load together – Modeling and simulation of stand-alone systems - Applications.

UNIT – III  GRID CONNECTED PV SYSTEMS  9L+6P
Schematics and Components - Balance of system Components - Interface Components – Net metering & Gross metering - Feasible operating region of inverter at different power factor - Active power filtering with real power injection - Modeling and simulation of grid connected systems - Floating PV panel.

UNIT – IV  HYBRID SYSTEMS  9L+6P
Need for Hybrid Systems - Range and type of Hybrid systems - Case studies of Diesel-PV, Wind-PV, Microhydel-PV, PV-Hydrogen, Electric and hybrid electric vehicles - Comparison and selection criteria for a given application - Modeling and simulation of hybrid systems.

UNIT – V  GRID CODE REQUIREMENTS AND STANDARDS  9L
CEA technical standard for connectivity to the grid: voltage, frequency, LVRT, HVRT, power factor, harmonics, DC injection, flicker – IEEE 2800: Q vs P and Q vs V reactive power capability, power quality, protection, low and high voltage ride through – low and high frequency ride through.

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1  Apply principle of evidence-based photovoltaic technology
CO2  Provide accurate schematic of stand-alone PV systems and BOS
CO3  Provide accurate schematic of grid-connected PV systems and BOS
CO4  Select appropriate hybrid system for different applications
CO5  Design and simulate the stand-alone and grid connected system.

REFERENCES:
Practical

1. Determination of IV characteristics of Solar Cell
2. Comparative study on Solar Module Characteristics (Series and parallel configuration)
3. Performance evaluation of SPV Stand-alone Systems under various operating conditions
4. Study on Augmentation of Solar panel performance
5. Performance evaluation of Simple Hybrid Systems
6. Performance evaluation of Solar grid tied system
7. Performance evaluation of Solar PV Water Pumps
8. Study on Charging and Discharging Cycles of the batteries.
9. Investigation of Thermal management of Solar PV system
10. Testing the efficiency of a Solar Cell at Varying Wavelengths
11. Design a simple solar stand-alone system
12. Design a simple solar water pumping system
13. Study and prepare the single line diagram for a solar power plant of minimum capacity of 1 MW

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OBJECTIVES:
The objective of this course is to enable the students to acquire knowledge on various types of solar thermal collectors and its applications. This course will also help students to carry out the design and modeling of active and passive types of solar thermal systems.

UNIT – I SOLAR THERMAL COLLECTORS 9L+10P

UNIT – II SOLAR WATER HEATING SYSTEMS 9L+10P

UNIT – III SOLAR COOLING SYSTEMS 9L

UNIT – IV SOLAR THERMAL APPLIANCES 9L+10P

UNIT – V DESIGN AND MODELING OF SOLAR THERMAL SYSTEMS 9L
Active Systems: The f - Chart Method for Liquid Systems and Air Systems – Utilizability Methods – The $\overline{f}$, f-chart Method

OUTCOMES:
Upon completion of this course, the students will be able to:
1. Elucidate the technical process of solar thermal collectors
2. Explicate the spectrum of possible water heating system to assist the industrial process
3. Articulate the technical and economic viability of solar cooling systems
4. Measure and evaluate different solar energy technologies through knowledge of the physical function of the devices
5. Design the solar thermal systems and an accessible way to a target group with basic technical skills.

REFERENCES:

**Practical**

1. Evaluate the thermal performance of Solar Water Heater in Thermo-Syphon mode.
2. Evaluate the thermal performance of Solar Water Heater in forced convection mode.
4. Performance of solar water heater with varying inclination angle of collector
5. Performance enhancement of solar box cooker with and without thermal energy storage system.
7. Performance enhancement of Solar Air Collector for drying application (Active and passive type).
8. Augmentation of heat transfer on Parabolic Trough Collector with various absorber tubes.
9. Performance study on Solar dish collectors for various applications.
10. Performance study on PVT Air Collector using different HTF
11. Study of solar thermal system using Thermal image camera

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**EY3251 COMPUTATIONAL FLUID DYNAMICS FOR ENERGY SYSTEMS**  

**OBJECTIVE:**  
To make students familiarize with the concepts of discretization techniques using finite difference and finite volume method for various transport phenomena related problems.

**UNIT – I GOVERNING DIFFERENTIAL EQUATIONS AND DISCRETISATION TECHNIQUES**  

**UNIT – II DIFFUSION PROCESSES: FINITE VOLUME METHOD**  

**UNIT – III CONVECTION - DIFFUSION PROCESSES: FINITE VOLUME METHOD**  
One dimensional convection – diffusion problem, Central difference scheme, upwind scheme – Hybrid and power law discretization techniques – QUICK scheme. – Assessment of discretization scheme properties.

**UNIT – IV INCOMPRESSIBLE FLOW PROCESSES: FINITE VOLUME METHOD**  
Discretization of incompressible flow equations – Stream Function – Vorticity methods - Pressure based algorithms, SIMPLE, SIMPLER, SIMPLEC & PISO algorithms.

**UNIT – V TURBULENCE**  
Kolmogorov’s Theory - Turbulence - Algebraic Models, One equation model & $k – \varepsilon, k – \omega$ models - Standard and High and Low Reynolds number models.

**TOTAL: 60 PERIODS**

**OUTCOMES:**  
Upon completion of this course, the students will be able to:

- **CO1** Know the differences between various discretization techniques.  
- **CO2** Learn the finite volume based numerical method for solving diffusion heat transfer problems.  
- **CO3** Learn the finite volume based numerical method for solving convection-diffusion heat transfer problems.  
- **CO4** Understand the discretization of incompressible flow governing equations  
- **CO5** Recognize the impact of various turbulence modelling

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OBJECTIVES:
Learn the simulation analysis software(s) and get expertise with the computational procedure to study the behavior of various solar photovoltaic and thermal energy systems and numerically solve the problems related to solar energy technology, heat transfer & fluid flow.

LIST OF EXPERIMENTS
1. Heat transfer analysis:
   (a) Conduction
   (b) Convection – Internal flow & Velocity boundary layer
   (c) Radiation
2. Design and numerical analysis of a solar flat plate collector
3. Design and numerical analysis of a solar photovoltaic panel
4. Design and numerical analysis of a solar air dryer & solar still
5. Design and numerical analysis of a thermal energy storage tank
   (a) Sensible heat medium
   (b) Latent heat medium
6. Performance study of a solar photovoltaic panel involving shading effects
7. Numerical analysis in the receiver section of a concentrating solar collector with varying heat transfer fluids
8. Numerical analysis of critical radius of insulation in a pipe carrying hot fluid
9. Numerical heat transfer analysis in a helical coil tube
10. Study experiment on,
    (a) IoT applications for a solar farm.
    (b) Drone applications for solar farm surveying, mapping, and inspection
    (c) Rooftop PV planning and Hybrid PV system
11. Simulation of Thermal Power Plant Cycles, Configuration, Instrumentation and Controls

TOTAL: 60 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 Use modern software tools to simulate, analyze and optimize any solar PV / thermal system
CO2 Investigate the various process parameters influencing the performance of the solar PV / thermal system
CO3 Illustrate the outcomes in brief containing the details of the domain analyzed in the form of a detailed report

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OBJECTIVE:
To understand, learn and apply the principles and practices of Solar Thermal and Solar Photovoltaic systems.

GUIDELINES:
- Each student has to undergo Industrial training for a minimum period of four weeks during the upcoming summer vacation (i.e., between II and III Semester).
- The Internship has to be undergone continuously for the entire period.
- The Internship must be carried out in a solar related industry
- The End Semester Examination must be conducted at the start of III Semester.
- The mark will be based on the project report (Introduction; Project or Training details; Techno Economics; Discussion; and Conclusion) and their presentation followed by oral examination on the same by internal examiner.

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 Apply the solar energy principles in various systems
CO2 Assess the performance of solar PV / thermal system
CO3 Prepare and present a detailed project report professionally

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OBJECTIVE:
The main learning objective of this course is to prepare the students for identifying a specific problem for the current need of the society and or industry, through detailed review of relevant literature, developing an efficient methodology to solve the identified specific problem.

GUIDELINES:
- Each PG student shall work individually on a selected specific topic in the area of SOLAR ENERGY which shall be approved by the Head of the Division under the supervision of a Faculty Member (Guide / Supervisor) who is familiar in the selected specific topic. The selected specific topic maybe theoretical and or experimental and or simulation and or case study. The students’ Project Work – Phase I shall be evaluated through Internal Examination and End Semester Examination.
- The Internal Examination must be conducted periodically (Zeroth, First, Second and Third) through Project Work Review Presentation Meetings followed by questions from the panel of Review Committee Members comprising of two expert faculty members and a project coordinator.
- At the end of the semester, a detailed report on the work done by the PG student must be submitted with the approval from the Guide/Supervisor and the Review Committee Members. The Project Work – Phase I Report must contain the Introduction with clear definition along with detailed review of relevant literature on the selected specific problem; an efficient methodology to solve the selected specific problem along with necessary hypothesis and or experimental setup and or simulation and or case study for carrying out the research project work along with preliminary results; discussions, relevant conclusions and future direction along with specified references.
- The End Semester Examination must be conducted through Project Work Presentation followed by questions from the panel of Examiners comprising an External Examiner and Project Coordinator as Internal Examiner.

TOTAL: 180 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 Demonstrate a sound technical knowledge in their selected project topic.
CO2 Select and identify the problem statement along with scope and boundary; assimilate detailed review of relevant literature; formulate an efficient methodology to solve the selected specific problem.
CO3 Propose engineering design solutions to complex problems using a systematic approach.

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OBJECTIVE:
The main learning objective of this course is to prepare the students for solving the specific problem for the current need of the society and or industry, through the formulated efficient methodology, and to develop necessary skills to critically analyse and discuss in detail regarding the project results and making relevant conclusions.

GUIDELINES:
- The student may continue to work on the Project Work – I’s selected topic as per the formulated efficient methodology under the same Faculty Member (Guide/Supervisor). The students’ Project Work – II shall be evaluated through Internal Examination and End Semester Examination.
- The Internal Examination must be conducted periodically (First, Second and Third) through Project Work Review Presentation Meetings followed by questions from the panel of Review Committee Members comprising of two expert faculty members and a project coordinator.
- At the end of the semester, a detailed report on the work done by the PG student must be submitted with the approval from the Guide/Supervisor and the Review Committee Members. The Thesis (Project Work – II Report) must contain the Introduction with clear definition along with detailed review of relevant literature on the selected specific problem; an efficient methodology to solve the selected specific problem along with necessary theoretical hypothesis and or experimentation and or simulation and or case study for carrying out the research project work along with complete results with critical analysis and detail discussions, followed by relevant conclusions, along with specified references.
- The End Semester Examination must be conducted through Project Work Presentation followed by questions from the panel of Examiners comprising an External Examiner and Project Coordinator as Internal Examiner.

TOTAL: 360 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 Demonstrate a sound technical knowledge in their selected project topic.
CO2 Propose product design & development solutions to complex problems using a systematic approach.
CO3 Demonstrate the knowledge, skills and attitudes of a professional engineer to take up any challenging practical problem in the field of engineering design and find optimum solutions to it.

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OBJECTIVES:
The objective of this course is to provide in-depth knowledge to students on power generation and distribution based on solar thermal and solar PV energy conversion principles. In addition, this course is intended to impart knowledge on students about energy policies in India and across the globe.

UNIT – I  SOLAR THERMAL POWER GENERATION  9
Solar Parabolic trough - Design considerations, tracking and control systems - Thermal design of receivers - Solar parabolic dish - Design considerations, Sterling engine, Brayton cycle, tracking and control systems - Solar tower concepts - Tower design - Heliostat design - Receiver types, tracking and control systems - Performance study, site selection and land requirement for the above technologies - Techno-economic analysis of solar thermal power plants.

UNIT – II  SOLAR PHOTOVOLTAIC POWER GENERATION  9
Solar PV technologies overview - Stationary and concentrated PV - Inverter and control technologies - Master slave inverter system design - Standalone systems - Grid connected systems - Hybridization, synchronization, and power evacuation - Site selection and land requirements - Techno-economic analysis of solar PV power plants - Environmental considerations, Recent developments in solar PV materials.

UNIT – III  SOLAR ENERGY POLICY PLANNING  9
Elements in policy making in solar energy - Components of policy making - Essentials and other requirements - Pre-requirements of policy planning - Models for planning for effective policy making - Data requirements for policy plans - Monitoring and assessments of policies - Global policy pronouncement.

UNIT – IV  SOLAR ENERGY REGULATIONS AND POLICY PROGRAMMES  9

UNIT – V  POLICY MANAGEMENT CHALLENGES  9
Challenges for planning and policies - Issues of subsidization - Entrepreneurship development and management challenges - Issues in entrepreneurship development and management challenges in renewable energy sector in India – Production – Storage - Transmission and distribution - End-use - Pricing, etc

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1  Design power generation based on solar thermal power technologies.
CO2  Design power generation based on stand-alone and concentrating PV technology.
CO3  Know the Indian and global energy policy scenario.
CO4  Know the Indian and global energy policy programme
CO5  Understand the challenges in energy policy management.

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OBJECTIVES:
The major objective of this course is to enable students to learn the working principle of different solar energy appliances such as PV cell, solar furnace, solar desalination system and solar-pumped laser technology. This course will also help students to understand the different ways of improving its operating efficiency.

UNIT – I  SOLAR LIGHTING  9

UNIT – II  SOLAR COOKING  9

UNIT – III  SOLAR FURNACE  9

UNIT – IV  SOLAR DESALINATION  9

UNIT – V  SOLAR LASER  9

TOTAL: 45 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1  Familiar with concepts of solar home lighting and solar street lighting systems.
CO2  Identify the solar cooker technologies for suitable applications.
CO3  Design solar furnace of a known rating capacity
CO4  Aware about various desalination techniques and material problems in solar still
CO5  Apply the principles of solar-pumped laser and critically analyze the system

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OBJECTIVES:
The objective of this course to enhance the knowledge of the students on design and implementation of power electronic devices for off-grid and grid connected renewable energy systems. This course will also help students to address power quality issues in renewable energy systems.

UNIT – I  INTRODUCTION TO RENEWABLE ENERGY SYSTEMS  9
Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission) - Qualitative study of different renewable energy resources: Solar, wind, ocean, Biomass, Fuel cell, Hydrogen energy systems and hybrid renewable energy systems

UNIT – II  ELECTRICAL MACHINES FOR RENEWABLE ENERGY CONVERSION  9
Renewable energy conversion systems: fundamental principle of operation of self-excited induction generator, squirrel cage induction generator, doubly fed induction generator, synchronous generator, permanent magnet synchronous generator; Grid related problems: harmonic reduction and power factor improvement

UNIT – III  POWER CONVERTERS  9
Solar: Block diagram of solar photo voltaic system - Principle of operation: line commutated converters (inversion-mode) - Boost and buck-boost converters- selection of inverter, battery sizing, array sizing

UNIT – IV  ANALYSIS OF WIND AND PV SYSTEMS  9
Stand-alone operation of fixed and variable speed wind energy conversion systems and solar system- Grid connection Issues -Grid integrated PMSG and SCIG Based WECS Grid Integrated solar system

UNIT – V  HYBRID RENEWABLE ENERGY SYSTEMS  9
Need for Hybrid Systems- Range and type of Hybrid systems- Case studies of Wind-PV Maximum Power Point Tracking (MPPT).

TOTAL: 45 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1  Analyze the various conversion techniques in renewable energy technologies
CO2  Apply the various mechanisms for the conversion of renewable energy sources.
CO3  Identify the appropriate power converters for renewable energy systems.
CO4  Implement the different conversion mechanisms for wind and solar systems.
CO5  Recognize the importance of various hybrid renewable energy systems

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OBJECTIVES:
The objective of this course is to enable the students to acquire knowledge on smart grid, different options of architectural design and communication technology for various aspects of smart grid. This course will also help students to carry out system and stability analysis in smart grid, renewable energy sources and storage integration with smart grid.

UNIT – I  INTRODUCTION TO SMART GRIDS
Evolution of Electric Grid, Concept, Definitions and Need for Smart Grid, Smart grid drivers, functions, opportunities, challenges and benefits, Difference between conventional & Smart Grid, National and International Initiatives in Smart Grid.

UNIT – II  SMART GRID TECHNOLOGIES (Transmission)
Technology Drivers, Smart energy resources, Smart substations, Substation Automation, Feeder Automation, Transmission systems: EMS, FACTS and HVDC, Wide area monitoring, Protection, and control.

UNIT – III SMART GRID TECHNOLOGIES (Distribution)
DMS, Voltage control, Fault Detection, Isolation and service restoration, Outage management, High-Efficiency Distribution Transformers, Phase Shifting Transformers, Plug in Hybrid Electric Vehicles (PHEV).

UNIT – IV  SMART METERS AND ADVANCED METERING INFRASTRUCTURE
Introduction to Smart Meters, Advanced Metering infrastructure (AMI) drivers and benefits, AMI protocols, standards and initiatives, AMI needs in the smart grid, Phasor Measurement Unit (PMU), Intelligent Electronic Devices (IED) & their application for monitoring & protection.

UNIT – V  HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATIONS
Local Area Network (LAN), House Area Network (HAN), Wide Area Network (WAN), Broadband over Power line (BPL), IP based Protocols, Basics of Web Service and CLOUD Computing to make Smart Grids smarter, Cyber Security for Smart Grid.

TOTAL: 45 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 Students will develop more understanding on the concepts of Smart Grid and its present developments.
CO2 Students will study about different Smart Grid technologies.
CO3 Students will acquire knowledge about different smart meters and advanced metering infrastructure.
CO4 Students will have knowledge on power quality management in Smart Grids
CO5 Students will develop more understanding on LAN, WAN and Cloud Computing for Smart Grid applications.

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OBJECTIVES
To make aware of the importance and to facilitate students with the required knowledge of passive solar architecture, passive systems for both heating and cooling of buildings

UNIT – I INTRODUCTION

UNIT – II CLIMATE AND HUMAN THERMAL COMFORT

UNIT – III PASSIVE COOLING OF BUILDINGS
Passive cooling concept - Solarium Passive cooling - Ventilation cooling - Nocturnal radiation cooling - Evaporative cooling - Roof surface evaporative cooling (RSEC) - Direct evaporative cooling using drip-type (desert) coolers — Radiation cooling - Earth coupling - Basic principles and systems.

UNIT – IV PASSIVE SOLAR HEATING OF BUILDINGS

UNIT – V BUILDING RATING SYSTEMS

TOTAL: 45 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 The fundamental concepts of solar passive architecture were understood along with examples and case studies.
CO2 The concepts of passive solar heating and cooling of buildings, human comfort conditions.
CO3 Aware about various building materials.
CO4 Know the zero energy building concept and rating systems.
CO5 Learn the energy management of buildings and green globe assessment standards.

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OBJECTIVES:
To understand the significance, need and applications of nanomaterials for solar systems and to impart the knowledge on latest cutting-edge technologies in the field of fuel cell.

UNIT – I  PROPERTIES OF NANOMATERIALS  9

UNIT – II  NANOMATERIALS FOR SOLAR THERMAL CONVERSION  9
Conversion of thermal energy - Nanostructures and nanomaterials, materials selection criteria, particle-scale effect. Phase compositions on nanoscale microstructures. Nanoparticles for conduction heat transfer, coatings on fins.

UNIT – III  NANO APPLICATIONS IN THERMAL ENERGY STORAGE  9

UNIT – IV  NANOMATERIALS FOR PHOTOVOLTAICS  9

UNIT – V  NANOMATERIALS IN FUEL CELL APPLICATIONS  9
Use of nanostructures and nanomaterials in fuel cell technology - high and low temperature fuel cells, cathode and anode reactions, fuel cell catalysts, electrolytes, ceramic catalysts. Use of nanotechnology in hydrogen production and storage.

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1  Know the properties of nanomaterials and types
CO2  Apply the appropriate nanomaterials for thermal application
CO3  Comprehend the nanomaterial usage in thermal storage application
CO4  Understand the use of nanomaterial in photovoltaics
CO5  Recognize and choose appropriate nanomaterials for fuel cells

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OBJECTIVES:
The Objective of the course is to apply the structural analysis concepts and wind load calculation for solar energy system structure design.

UNIT – I  PREAMBLE TO STRENGTH OF MATERIALS  9

UNIT – II  PRINCIPLE OF STRUCTURES  9

UNIT – III  STRUCTURAL ANALYSIS  9

UNIT – IV  ANALYSIS OF FRAMES, TRUSSES AND COMPOSITE STRUCTURES  9

UNIT – V  WIND LOADS  9
Wind load on building structures, wind load on solar collectors and PV panels mounted on the roof. Barriers - Varieties of materials and air barrier configuration.

TOTAL: 45 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:

CO1 Apply the concepts of strength of materials for solar structure problems
CO2 Understand the principle of structures
CO3 Analyse the structure statistically for its stability and fitness
CO4 Follow different methods of load calculation to examine the various structures for its stability
CO5 Recognize importance of wind load on solar system structures and calculate wind load

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OBJECTIVES:
To comprehend the materials that has been implicated in various forms of solar energy sources and its storages and to impart knowledge on solar system balance and analysis with reference to its cost.

UNIT – I  MATERIALS FOR SOLAR COLLECTORS  9

UNIT – II  MATERIALS FOR SOLAR CELLS  9

UNIT – III  THIN FILM AND NOVEL SOLAR CELL MATERIALS  9

UNIT – IV  ENERGY STORAGE MATERIALS  9

UNIT – V  BALANCE OF SYSTEM MATERIALS & COST ANALYSIS  9

TOTAL: 45 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:

CO1  The students will get fundamental understanding on principles of materials used in solar cells.

CO2  The students will be able to understand the structure-property relationship and appreciate novel developments in the materials.

CO3  To explain the concept and the diverse materials used for solar devices.

CO4  To explicate in depth knowledge of about solar cells, thermal energy storage and electrical energy storages.

CO5  To gather some idea of system balance and analysis with reference to its cost.
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OBJECTIVE:
The objective of this course is to provide in-depth knowledge to students on design of Solar Photovoltaic power plant along with its system components.

UNIT – I SELECTION OF SITE AND SHADOW ANALYSIS
PV module structure inter row spacing calculation - Pitch analysis - Selection of PV module tilt angle - Near shading object calculation - Site survey and plant assessment - Type of solar radiation – Irradiance assessment and comparison - Solar Radiation Data - Sun path Diagram - Defining the Position of the Sun - Solar Altitude - Geometric Effects - Tilting Solar Modules

UNIT – II SELECTION OF PV MODULE (CELLS AND BOM) AND SIZING

UNIT – III INVERTERS SELECTION AND SIZING (GRID CONNECTION AND OFF GRID)
Types of solar inverter - Selection of string /central / off grid inverter - Selection of power conditioning unit (PCU) - Sizing of solar inverter for roof top and grid connected projects - Selection and sizing of string inverter - Selection and sizing of central inverter - AC/DC overloading calculation and losses - Protection requirement of solar inverter - Passive and active protection - Anti- islanding protection - Mounting arrangement of string inverter - IEC/IEEE /Grid Compliance of inverters - Grid-Connected Inverters vs. Stand-Alone Inverters - Inverter Communication and remote monitoring - Inverter Products For Use In India – BoS Selection.

UNIT – IV SOLAR POWER PLANT SUBSTATION AND SWITCHYARD
Preparation of Protection SLD - Selection and sizing of Substation - Preparation of ring main and radial feeder SLD - Selection and sizing of Power transformer - Selection and sizing of Current transformer - Selection and sizing of PT/Isolator/Breaker - Construction of 33KV/132 KV substation - Construction of four pole structure - Construction of metering switchyard - Selection sizing of switchyard earthing

UNIT – V SOLAR POWER SYSTEM YIELD PERFORMANCE

OUTCOMES:
Upon completion of this course, the students will be able to:

CO1 Analyse the site selection and impact of shadow
CO2 Selection and sizing of PV module for Solar Power Plant
CO3 Provide the details on selection of inverter for the suitable applications
CO4 Select proper selection and design for substation and switchyard
CO5 Design and simulate the performance and economic projection of PV plants
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OBJECTIVE:
Gain an understanding of the energy situation at both the national and global levels and utilize available resources to predict and model energy demand while considering current policies.

UNIT – I ENERGY STRUCTURE

UNIT – II FORECASTING MODEL

UNIT – III OPTIMIZATION MODEL

UNIT – IV PROJECT MANAGEMENT

UNIT – V ENERGY POLICY & SCHEMES

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 Gain knowledge on the National and Global energy scenario.
CO2 Use various techniques to perform Energy Forecasting and modeling.
CO3 Develop optimization model for energy planning.
CO4 Caliber to execute a project with detailed economic analysis.
CO5 Understand the National and state energy policies.

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OBJECTIVE:
Understand the design principles of any thermal energy system and develop a model to arrive at the optimal solution and study the dynamic behavior of the same with a tradeoff between capital and operating cost using pinch point analysis.

UNIT – I DESIGN CONCEPTS

UNIT – II MODELLING AND SYSTEMS SIMULATION

UNIT – III OPTIMIZATION

UNIT – IV DETERMINISTIC SEARCH METHODS
Non-linear least square minimization – Levenberg-Marquardt, Conjugate gradient algorithm – case studies with deterministic search algorithms.

UNIT – V STOCHASTIC SEARCH METHODS
Introduction to random search methods – advantages and disadvantages, Genetic Algorithm. Other advanced algorithms – simulated annealing, Particle Swarm Optimization.

TOTAL: 45 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 Understand basic design principles of the thermal systems and the type of models suitable for further analysis.
CO2 Carry out the Simulation and Modelling of typical thermal energy systems.
CO3 Analyze the effect of constraints on the performance of thermal energy systems.
CO4 Develop the dynamic analysis of the thermal system with control system feedback arrangement.
CO5 Design, optimize and perform the Energy-Economic Analysis for any thermal system.

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OBJECTIVE:

The objective of this course is to provide a holistic view on design of experiments and statistical analysis of experimental data obtained from laboratory or industrial processes.

UNIT – I INTRODUCTION TO RANDOM VARIABLES AND PROBABILITY

Introduction to probability, Bayes’ theorem, Random variables - discrete and continuous, mean and variance, probability distribution functions - Binomial, Poisson, Normal, Weibull, Lognormal, Student-t, Joint probability distributions - marginal and conditional probability, covariance and correlation, bi-variate normal distribution function.

UNIT – II SAMPLING DISTRIBUTIONS AND ANALYSIS OF STATISTICAL INTERVALS

Sampling distribution and central limit theorem, General concept of point estimation - unbiased estimators, variance of point estimator, method of point estimation - maximum likelihood, Bayesian estimation, Confidence intervals with known and unknown variance, choice of sample size, guidelines for constructing confidence intervals.

UNIT – III HYPOTHESIS TESTING: SINGLE AND MULTIPLE SAMPLES

Statistical hypothesis - tests of statistical hypothesis, General procedure for hypothesis tests
Single sample case: tests on the mean of a normal distribution with known and unknown variance, testing for goodness of fit.
Two sample case: inference on the difference in means of two normal distributions with known and unknown variance, inference on the variances of two normal distributions and population proportions.

UNIT – IV ANALYSIS OF SIMPLE AND MULTIPLE LINEAR REGRESSION MODELS

Empirical models, simple linear regression, least square estimators, prediction of new observations and adequacy checking, correlation between parameters.
Multiple linear regression model, prediction of new observations and adequacy checking, multicollinearity.

UNIT – V DESIGN AND ANALYSIS OF SINGLE AND MULTIPLE FACTOR EXPERIMENTS

Completely randomized single-factor experiment - analysis of variance, multiple comparisons following ANOVA, residual analysis, and model checking, determining sample size. Random effect model - fixed Vs random effects, ANOVA and variance components. Randomized Complete Block Design (RCBD) - design and statistical analysis, multiple comparisons, residual analysis and model checking, Two-factor factorial experiments, 2^k factorial design - blocking and confounding, fractional replication, response surface methods.

OUTCOMES:

Upon completion of this course, the students will be able to:

CO1 Statistically analyse experimental data obtained from laboratory/industrial process
CO2 Structure engineering decision-making problems as hypothesis tests
CO3 Structure comparative experiments involving two samples as hypothesis tests
CO4 Develop empirical models from engineering data using linear regression, predict future observations, and establish a suitable prediction interval.
CO5 Design and conduct engineering experiments involving single and multiple factor.
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EY3061 ENERGY STORAGE TECHNOLOGIES

OBJECTIVE:
To understand the significance and need for various types of energy storage technologies and their uses for real world applications. This course will also enable students to understand the Green Energy Storage of Hydrogen and the challenges associated

UNIT – I INTRODUCTION TO ENERGY STORAGE

UNIT – II THERMAL ENERGY STORAGE SYSTEM

UNIT – III ELECTRICAL ENERGY STORAGE
UNIT – IV HYDROGEN ENERGY STORAGE


UNIT – V ALTERNATE ENERGY STORAGE TECHNOLOGIES


OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 Identify the energy storage technologies for suitable applications.
CO2 Apply the appropriate thermal energy storage methods suitably.
CO3 Introduce the concepts, types and working of various batteries.
CO4 Understand the use of Hydrogen as Green Energy for our Future.
CO5 Recognize and choose appropriate methods of Energy Storage and Hybrid Systems.

TOTAL: 45 PERIODS

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OBJECTIVES:
To study the basics of production and storage techniques of Green Hydrogen. This course will enable the student to gain knowledge on classifications, construction, working and applications of fuel cells.

UNIT – I HYDROGEN – BASICS AND PRODUCTION TECHNIQUES

UNIT – II HYDROGEN STORAGE AND APPLICATIONS

UNIT – III THERMODYNAMICS AND KINETICS OF FUEL CELL

UNIT – IV CLASSIFICATION OF FUEL CELLS
Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC, MFC – principle, construction and working – relative merits and demerits.

UNIT – V FUEL CELL APPLICATIONS AND ECONOMICS
Fuel cell usage for domestic power systems, large scale power generation, Automobile, Space. Economic and environmental analysis on usage of Hydrogen and Fuel cell. Future trends in fuel cells. – Green

TOTAL: 45 PERIODS

OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 Analyze the techniques of Green Hydrogen generation.
CO2 Apply the various options for Hydrogen storage.
CO3 Recognize the principle operations of fuel cell, types, its thermodynamics and kinetics.
CO4 Comprehend the different types of fuel cells.
CO5 Apply the fuel cells for domestic, automotive, space craft power generations and evaluate the techno-economics of a fuel cells.

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OBJECTIVES:
The objectives of this course is to expose the students in learning about industrial process heat and methods of using solar energy to supply heat for these processes. Also to apply techno-economic details for the related process heat industries.

UNIT – I INTRODUCTION
Solar energy – Availability and utilization - Historical background of solar industrial process heat (IPH) - Need of the day – Opportunities and challenges of industrial process heat - Characteristics of industrial process heat.

UNIT – II SOLAR ENERGY COLLECTORS FOR INDUSTRIAL PROCESS HEATING

UNIT – III INDUSTRIAL PROCESS HEATING SYSTEM
Introduction – Hot water industrial process heat system – Hot air industrial process heat system – Steam industrial process heat system – Problems involved with industrial process heat system – Case studies on industrial process heat.

UNIT – IV APPLICATIONS OF SOLAR INDUSTRIAL PROCESS HEAT
Industrial sectors and processes with the potential for solar thermal uses - Food and beverage industries - The textile and chemical industries - Power generation applications – Washing process – Drying process – Distillation and chemical process.

UNIT – V TECHNO ECONOMIC ANALYSIS
Elements of economic principle, economic calculation. Energy economics-basic concepts, unit cost of power generation from different sources, payback period, NPV, IRR and benefit cost analysis. Conventional and solar energy resources and costs. Direct and indirect costs, pricing system and project management.

COURSE OUTCOMES:
Upon completion of this course, the students will be able to:
CO1 The basic concepts of solar energy-related industrial process heat systems.
CO2 Students will have knowledge on materials for flat plate collector and their properties.
CO3 Students will acquire knowledge about industrial hot water, hot sir and steam heat system.
CO4 Learn the various applications of solar industrial process heat.
CO5 The techno-economic details for the related process heat industries were incorporated.

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OBJECTIVES:
The major objective of this course is to learn about the utilization of solar energy for cooling applications in both buildings and industries in economical way through the systems such as absorption, adsorption, desiccant and organic Rankine Cycles.

UNIT I THERMODYNAMIC CYCLES FOR SOLAR COOLING 9

UNIT 2 SOLAR THERMAL COLLECTORS AND STORAGE SYSTEMS 9
Non-concentrating solar collectors, concentrating solar collectors, Collector applications – Medium and high temperature – Sensible and Latent heat Storage, Heat transfer enhancement techniques, Thermal Chemical storages

UNIT 3 SOLAR THERMAL COOLING TECHNOLOGIES 9

UNIT 4 PV DRIVEN COOLING AND HEATING SYSTEMS 9
PV cell, Design of PV systems for Vapour compression cycles, Thermo electric cycle, Solar PV based chillers, Photovoltaic thermal systems - Energy and environment analysis – Thermo economic analysis for cooling applications

UNIT 5 ALTERNATE AND HYBRID COOLING SYSTEMS 9

Total : 45 Periods

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:
CO1 Analyze the performance of different thermodynamic solar cooling cycles.
CO2 Design the different types of solar collectors for a given cooling load.
CO3 Understand and Analyze the performance of solar thermal based chillers.
CO4 Design the solar PV powered cooling system
CO5 Apply various alternate and hybrid systems for cooling applications

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