Master of Technology

In

Energy Technology

Course Structure & Syllabus

Department of Mechanical Engineering

National Institute of Technology Hamirpur

Hamirpur (HP) – 177005, India

Course Structure of M.Tech. Energy Technology

SEMESTER-I

S. No.	Course No.	Course Name	Teaching Schedule			Hours/ Week	Credit
			L	T	P		
1.	EN-611	Foundation for Energy Resources	4	0	0	4	4
2.	EN-612	Solar Photovoltaic Technology	4	0	0	4	4
3.	EN-613	Bio-Energy and Biofuels	4	0	0	4	4
4.	EN-7MN	Programme Elective-I	4	0	0	4	4
5.	EN-7MN	Programme Elective-II	4	0	0	4	4
6.	EN-614	Energy Laboratory-I	0	0	4	4	2
Total			**20**	**0**	**4**	**24**	**22**

Programme Elective-I & II: List of Programme Electives is given in the Annexure.

SEMESTER-II

S. No.	Course No.	Course Name	Teaching Schedule			Hours/ Week	Credit
			L	T	P		
1.	EN-621	Solar Thermal Technology	4	0	0	4	4
2.	EN-622	Wind and Hydro Energy	4	0	0	4	4
3.	EN-623	Energy Efficiency, Audit and Management	4	0	0	4	4
4.	EN-7MN	Programme Elective-III	4	0	0	4	4
5.	EN-7MN	Programme Elective-IV	4	0	0	4	4
6.	EN-624	Energy Laboratory-II	0	0	4	4	2
Total			**20**	**0**	**4**	**24**	**22**

Programme Elective-III & IV: List of Programme Electives is given in the Annexure.

SEMESTER-III

S. No.	Course No.	Course Title	Hours/Week	Credit
1.	EN-800	M.Tech. Dissertation	---	20
Total				**20**

SEMESTER-IV

S. No.	Course No.	Course Title	Hours/Week	Credit
1.	EN-800	M.Tech. Dissertation	---	20
Total				**20**

Total Credit of the Programme=84

Annexure

List of Programme Electives

Program Elective-I

1.	EN-701	Fuel and Combustion
2.	EN-702	Waste Heat Recovery Systems
3.	EN-703	Energy Generation, Transmission and Distribution Systems

Program Elective-II

1.	EN-704	Computational Fluid Dynamics
2.	EN-705	Materials for Energy Applications
3.	EN-706	Energy Generation from Waste

Program Elective-III

1.	EN-707	Fuel Cells and Hydrogen Energy
2.	EN-708	Energy Storage Systems
3.	EN-709	Computational Heat Transfer in Energy Systems

Program Elective-IV

1.	EN-710	Modelling and Simulation
2.	EN-711	Nuclear Power Technology
3.	EN-712	Energy Management

Couse Name	:	**Foundation for Energy Resources**
Course Code	:	**EN-611**
Course Type	:	**Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- This course enables to understand various conventional and non-conventional energy resources.
- To provide basic concept related to thermodynamics, fluid machines, heat transfer and electrical machine**.**

Course Content

Renewable Energy Resources

Renewable Energy potential, Basic concepts and working principals of : Solar Energy, Wind Energy, Bio-Energy, Hydro, Tidal energy, Ocean energy, Nuclear Energy, Geothermal Energy, Magneto-hydro-dynamic (MHD) energy conversion, Fuel Cells, Waste to Energy Conversion, Hydrogen energy.

Non-Renewable Energy Resources

Fossil and Mineral Energy Resources, Details of Coal, Peat, Oil, Natural Gas and Nuclear Resources, Recovery of Fossil Fuels, Classification and Characterization of Fossil fuels. Working principles of power generation through conventional fuels. Energy Conversion routes, Direct and indirect way of Energy Conversion

Thermodynamics

First law of Thermodynamic & its applications, Second law of Thermodynamic and its Application, Irreversibility & Energy basic power generation cycles, psychometric & use of psychometric chart.

Fluid Mechanics

Stress – Strain relation & viscosity, Mass & Momentum balance, Flow through pipe, Navier Stokes equation.

Heat Transfer

Conduction, Convection, radiation heat transfer, overall heat transfer coefficient, heat exchangers.

Electrical Machines:

Transformer, Induction motor and generators, Synchronous generators, characteristics and applications; DC machines: characteristics and Applications

Power systems:

Load and load duration curves, Introduction to power generation, transmission and distribution, power systems losses and compensation, High voltage AC (HVAC) and High voltage DC (HVDC) transmission; Interconnected Grid system, Introduction to Smart grid.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Apply energy conversion device principle and evaluate their operation and performance.

CO2: Identify the working principle of different resources of energy.

Books and References

1. Energy Thermodynamics by P.K. Nag, Tata McGraw-Hill.
2. Solar Energy- Principles of thermal collection and storage by SP Sukhatme, Tata McGraw-Hill, New Delhi.
3. Solar Engineering of Thermal Processes by JA Duffie and WA Beckman, John Wiley, NY.
4. Heat Transfer by I.ncropera, Tata McGraw- Hill.
5. A Text Book in Electrical Technology by Theraja B. L. and Theraja A. K., S. Chand and Co.
6. Generation, Distribution and Utilization of Electrical Energy by Wadhwa C. L.; New Age International
7. Basic Electrical Engineering by Kothari D. P. and Nagrath I., McGraw Hill, India
8. Fluid Flow by White F.M. Viscous, McGraw-Hill New York.

Couse Name : **Solar Photovoltaic Technology** Course Code : **EN-612** Course Type : **Core**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To make students understand the fundamental theory governing the photovoltaic devise and make them carry out preliminary system design.

Course Content

Solar Radiation:

Sun as Energy Source, Solar Radiation at The Earth's Surface, Solar Radiation Geometry, Solar Time and Equation of Time, Sun Earth angles, Sun path diagram, Sunshine hours, Measurement of Solar Diffuse, Global and Direct Solar Radiation, Equipments, Estimation of Solar radiation on horizontal and tilted Surfaces, Global Solar radiation data, Indian Solar Radiation data analysis

Solar Cells

Conversion of Solar energy into Electricity - Photovoltaic Effect, Equivalent Circuit of the Solar Cell, Analysis of PV Cells: Dark and illumination characteristics, Figure of merits of solar cell, Efficiency limits, Variation of efficiency with band-gap and temperature, Efficiency measurements, High efficiency cells, Recent developments in Solar Cells, Role of nano-technology in Solar cells

Fabrication Technology for Solar Cells

High efficiency multi-junction solar cell, Quantum well solar cell, Technology for the fabrication of thin film cells, Optical concentration, Effect of temperature on Cell performance, Thermo photovoltaic effect

Solar Photovoltaic System Design

Solar cell array system analysis and performance prediction, Shadow analysis: Reliability, Solar cell array design concepts, PV system design, Design process and optimization: Detailed array design, Voltage regulation, Maximum tracking, Quick sizing method, Array protection.

Solar Photo Voltaic System Testing

Sun Simulator, Testing and performance assessment of Solar PV generator, Electronic Control and Regulation, Power Conditioning, Converters and inverter, Concentrating system, System design and configuration

SPV Power Systems

Centralized and decentralized SPV systems, Stand alone, hybrid and, grid connected system, System installation, Operation and Maintenance, Application of PV for lighting, Water pumping. Refrigeration, Telecommunication, Cathodic Protection, Solar PV Power Plant-Status-Case Studies, Hybridization Engineering, Hybrid systems, Grid integration. Building Integrated PV Systems, PV market analysis and Economics of SPV systems.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Predict the performance of solar photovoltaic device and analyze its performance.

CO2: Carry out of photovoltaic systems.

Books and References

1. Fundamentals of Solar Cells: PV Solar Energy Conversion by AL Fahrenbruch and RH Bube, Academic Press, New York.
2. Principles of Solar Engineering by F Kreith and JF Kreider, McGraw-Hill.
3. Solar Photovoltaics. Fundamental Technologies and Application by Chetan Singh Solanki, PHI Publicaton.

Couse Name : **Bio- Energy and Biofuels** Course Code : **EN-613** Course Type : **Core**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- The course provides an understanding of the processes for converting biomass to fuels by various approaches. In addition, develops potential to evaluate technical and economical feasibility & sustainability of energy production from biomass.

Course Content

Biomass Energy Potential:

Indian and global scenario, Life Cycle Analysis, Sustainability Criteria of Biofuels and Biomass

Thermo-chemical conversions

Thermal Decomposition Mechanisms of Bio-Renewable: Direct Combustion, Technology of Biomass gasification, Pyrolysis , Hydrothermal Liquefaction of Bio-renewable Feedstocks, Direct Liquefaction Chemical Conversion Hydrolysis and hydrogenation, Solvent extraction of hydrocarbons, Solvolysis of wood, Chemicals from biomass

Bio- Energy Systems

Biomass Gasifiers: Principle, Design of Bio mass Gasifiers, updraft gasifier, downdraft gasifier, zero carbon biomass gasification plants, applications for cooking, electricity generation, Gasifier Engines, Operation of spark ignition and compression ignition engine with wood gas, methanol, ethanol and biogas, Biomass integrated gasification/combined cycles systems. Biogas Systems: Technology of Bio-gas production, Biogas Plants, Digester types, Digester design, Chemical kinetics and mathematical modeling of bio-methanation process, Dung, Vegetable Waste and Night Soil and Municipal Waste based Bio -gas plants, Lighting, Electricity generation**,** Bio gas Bottling Plant Technology, Application of Bio gas slurry in agriculture, Design of Biogas for cold climates

Bio-ethanol

Bio-ethanol feed stocks, Fuel Properties of ethanol, Ethanol from Biomass, Bio-ethanol production by fermentation of Carbohydrates

Bio-diesel

Production methods of Bio-diesel: Fuel quality, standards and Properties, Availability of Raw materials for bio-diesel, Applications, Bio-diesel potential in India

Energy from Algae

Algae Cultivation, Photo-bioreactors, Harvesting, Sewage and Waste water growth conditions, algae biomass, algal meal/cake, Integration of CO2 emitting industries for growth of Algae, Other applications of Algae: food, pigment etc.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Assess the biomass resource, appropriate conversion technology for the given biomass resource & end use.

CO2: Identify potential solution to supply limitation & environmental issues related with biomass waste energy resources.

Books and References

1. Bio-fuels: biotechnology, chemistry, and sustainable development by DM Mousdale, CRC Press.
2. Renewable Energy by B Sorensen, Academic press, New York.
3. Renewable energy: Power for a sustainable future by G Boyle (Ed), Oxford, GROUP.

Couse Name : **Energy Laboratory-I** Course Code : **EN-614**	
Contact Hours/Week: **4P**	Course Credits: **02**

Course Objectives

- To learn the practical applicability of the theoretical concepts that have been studied in the class room.

Course Content

List of Experiments

1. To study the I-V & PV characteristics of solar PV module with varying radiation and temperature label and series and parallel combination of PV module using the following instruments
   - **a.** With Module Testing Kit
   - **b.** With Solar Power Analyzer Kit
2. To study the effect of variation in the tilt angle on PV module power.
   - **a.** To study the effect of shading on module output power.
   - **b.** To find the optimum tilt angle for a location.
3. To study the characteristics of Solar PV module under standard test condition using Sun Simulator.
4. To study the performance of Hydrogen Fuel Cell.
5. Heating and cooling tests on Paraboloid/Dish type concentrator cooker.
6. Thermal testing of Box type solar cooker: Determination of first (F_1) and second figures (F_2) of merit.
7. Measurement of solar radiation and sunshine hours
   - **a.** To measure hourly value of global and diffuse radiation incident on a horizontal surface on a clear day using shaded and unshaded pyranometers and to compare these values calculated from ASHARE co-relation.
   - **b.** To measure the beam normal radiation using pyrheliometer and compare it with that calculated from global and diffuse radiation measured by pyranometer.
   - **c.** To determine sunshine hours and peak sunshine hours
8. Calibration of given thermocouple /RTD with the help of reference Platinum Resistance Thermometer (PRT) and dry calibration bath.
9. To calculate the moisture percentage and ash percentage in a sample (biomass).
10. To estimate the solar thermal receives collection efficiency in case of parabolic dish collector.

Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the working principle of solar photovoltaic cell, fuel cells & biofuels.

CO2: Do testing and performance analysis of photovoltaic cell under standard test condition.

Couse Name :	**Solar Thermal Technology**	
Course Code :	**EN-621**	
Course Type :	**Core**	
Contact Hours/Week:	**4L**	Course Credits: **04**

Course Objectives

- To understand the basic concept of solar energy and performance of various type of solar collector.
- To develop skills in critical thinking and reasoning about issues associated with direct and indirect use of solar energy.

Course Content

Flat-plate Collectors

Liquid Flat Collector, Materials for Flat plate Collectors , Energy balance for Flat Plate Collectors, Overall Heat Loss Coefficient, heat transfer between Parallel surfaces , Heat capacity effect, Testing methods, Types of Flat Plate Collectors: Liquid Flat Plate Collectors, Air flat-plate Collectors-Thermal analysis, Evacuated tubular collectors. Design of solar heating system.

Solar Thermal Energy Storage

Solar Energy Storage, Sensible storage, Latent heat storage, Thermo-chemical storage, Design of storage system.

Concentrating Collector Designs

Classification, design and performance parameters, tracking systems, Compound parabolic concentrators, parabolic trough concentrators, Concentrators with point focus, Heliostats.

Vapor Absorption Refrigeration cycle

Water, ammonia and lithium bromide-water absorption refrigeration systems, Solar operated refrigeration systems, solar desiccant cooling, Current Status of Solar cooling.

Industrial Applications of Solar Heat

Temperature requirements, consumption pattern, Solar Passive Heating and Cooling, Solar Thermal Power Plant, Modeling of Solar Thermal Systems, Solar Desalination, Solar Drying, Solar Cooking, Solar Greenhouse technology: Fundamentals, design, modeling and applications in agriculture and space heating.

Design of Solar Heating Systems

Design and Sizing of Solar Heating Systems, f – chart method and utilizability methods of solar thermal system evaluation.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Evaluate the choice of solar collector for a given application.

CO2: Evaluate and analyze the performance of solar energy system by utilizing suitable mathematical model.

Books and References

1. Solar Energy: Principles of Thermal Collection and Storage by SP Sukhatme, Tata McGraw-Hill.
2. Solar Engineering of Thermal Processes by JA Duffie and WA Beckman, John Wiley.
3. Solar Energy: Fundamentals and Applications by Garg, J Prakash, Tata McGraw Hill, New Delhi.
4. Solar Thermal Engineering System by GN Tiwari, S Suneja, Narosa Publishing House, New Delhi.

Couse Name :	**Wind and Hydro Energy**	
Course Code :	**EN-622**	
Course Type :	**Core**	
Contact Hours/Week:	**4L**	Course Credits: **04**

Course Objectives

- To understand the process of generation of wind and hydropower, its potential & energy extraction.
- To understand the aerodynamic principle of turbine blade design.
- To understand the recent developments and technologies in the wind & hydro energy.

Course Content

Wind energy basics

Atmospheric circulations, classification, factors influencing wind, wind shear, turbulence, wind speed monitoring, Wind resource assessment, Weibull distribution

Power in the wind

Bentz limit, Wind energy conversion systems: classification, applications, power, torque and speed Characteristics Aerodynamic design principles; Aerodynamic theories: Axial momentum, Blade element and Combine theory, Rotor characteristics, Maximum power coefficient, Tip loss correction.

Wind Turbines

Wind turbine design considerations: methodology, theoretical simulation of wind turbine Characteristics wind pumps, performance analysis of wind pumps, design concept and testing, Principle of WEG: stand alone, grid connected; Hybrid applications of WECS; Economics of Wind energy Utilization, Wind energy Programm in India.

Hydropower plant

Hydrology, Resource assessment, Potential of hydropower in India, Classification of Hydropower Plants, Small Hydropower Systems: Overview of micro, mini and small hydro systems, Status of Hydropower Worldwide and India.

Hydraulic Turbines:

Types and operational aspects of turbines, classification of turbines, elements of turbine, selection and design criteria, geometric similarity operating characteristic curves; Speed and voltage regulation.

Site selection of hydropower plant

Selection of site for hydroelectric plant, Essential elements of hydroelectric power plant, Economics: cost structure, Initial and operation cost, environmental issues related to large hydro projects.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the operation of a wind farm & hydro power plant.

CO2: Able to do site selection for wind farm & hydro power plant.

Books and References

1. Wind Energy Systems by Johnson G. L., Prentice Hall.
2. Introduction to Hydro Energy Systems: Basics, Technology and Operation by Wagner H. and Mathur J, Springer.

Couse Name :	**Energy Efficiency, Audit and Management**	
Course Code :	**EN-623**	
Course Type :	**Core**	
Contact Hours/Week:	**4L**	Course Credits: **04**

Course Objectives

- To understand basic energy conservation and management principles.
- To identify the sources of energy loss and target saving.
- To carry out life cycle cost analysis and budgeting.

Course Content

Energy Efficiency Improvement in Electrical Systems

Improving Energy Efficiency in Electrical Systems, Electrical load management, maximum demand control.

Power Factor Power factor, power factor correction, selection and location of capacitors, performance assessment of PF capacitors and energy conservation opportunities

Electric Motors Motor efficiency, factor affecting motor performance, Energy saving opportunities in motors, energy efficient motors, soft starter with energy savers, motor efficiency measurements.

Transformers: Energy efficient transformers, factor affecting the performance of transformers

Electric Distribution Energy conservation opportunities, cables, switch gears, distribution losses, energy conservation in house electrical distribution system

Compressed Air Systems Compressor efficiency, efficient compressor operation, leakage test, factors affecting the performance and energy savings.

Pumps and Pumping System Energy conservation opportunities, Agricultural pumps, Solar PV Pumps

Fans and Blowers Energy efficient system operation, flow control strategies and energy conservation opportunities, Solar PV fans

Energy Audit and Management

Energy Management in Buildings and Industry, Energy Audit: Methodology, Data Collection, Techno-economic Analysis, Energy Audit Measurements **:** Energy Audit Instruments**,** Combustion Analysis, Temperature , Pressure Flow, Humidity, Energy, Power, Light Level measurements, HVAC, Furnaces and Ovens, Boilers and Steam Lines, Air Compressor and Compressed Air Distribution Lines, Chillers and Chilled Water Distribution Lines, Process Water Generation and Distribution Lines, Electrical Distribution, Transformers and Lines, Pumps, Fans and Blowers, Cooling Towers, Electrical Motors, Waste Heat Sources, Material Transport, Peak Load Equipments, Duties and responsibilities of Energy managers and Auditors, Case Studies of Energy Audit.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Design and develop energy efficient building.

CO2: Conduct energy audit and formulate and implement the energy conversation strategies.

Books and References

1. Industrial Energy Management and Utilization by LC Witte, PS Schmidt, DR Brown, Hemisphere Publication, Washington.
2. Hand book of Energy Audit by Sonal Desai Publisher Tata McGraw Hill.

Couse Name : **Energy Laboratory-II** Course Code : **EN-624**		
Contact Hours/Week: **4P**		Course Credits: **02**

Course Objectives

- To learn the performance of solar thermal collector, wind solar hybrid system under actual working condition.
- To learn the designing of hybrid system using software.

Course Content

List of Experiments

1. Renewable resource assessment (Wind, Solar) and analysis of data for different location.
2. Wind shear analysis for electrical power generation by a wind turbine.
3. To study the performance of Solar-Wind Hybrid System.
4. PV system designing for different locations in PVsyst simulation software.
5. Overview and system designing of hybrid system in HOMER software.
6. Evaluation of U_L, F_R and η in Thermosyphonic mode of flow with fixed input parameters for an indoor solar water with flat plate collector.
7. Evaluation of U_L, F_R and η in Thermosyphonic mode of flow with fixed input parameters for an indoor solar water with flat plate collector at different radiation levels.
8. Evaluation of U_L, F_R and η in force mode of flow with fixed input parameters for an indoor solar water with flat plate collector.

Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Performance analysis of solar water heater at different input parameters.

CO2: Performance of solar wind hybrid system in order to do system designing of hybrid system.

Couse Name : **Fuel and Combustion** Course Code : **EN-701** Course Type : **Program Elective-I**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To impart knowledge on fossil fuel and their combustion characteristics.
- To make students inquisitive about the problems of combustion.

Course Content

Basics of fuels

Modern concepts of fuel, Solid, liquid and gaseous fuels, composition, basic understanding of various properties of solid fuels - heating value, ultimate analysis, proximate analysis, ash deformation points; liquid fuels - heating value, density, specific gravity, viscosity, flash point, ignition point (self, forced), pour point, ash composition and gaseous fuels.

Coal as a source of energy

Coal reserves – World and India, Coal liquefaction process, various types of coal and their properties, Origin of coal, composition of coal, analysis and properties of coal, Action of heat on coal, caking and coking properties of coal; Processing of coal: Coal preparations, briquetting, carbonization, gasification and liquefaction of coal, Coal derived chemicals.

Petroleum as a source of energy

Origin, composition, classification of petroleum, grading of petroleum; Processing of petroleum: Distillation of crude petroleum, petroleum products, purification of petroleum products – thermal processes, catalytic processes, specifications and characteristics of petroleum products.

Natural gas and its derivatives

Classification of gaseous fuels – natural gas and synthetic gases, Natural gas reserves - World and India, properties of natural gas – heating value, composition and density

Principles of combustion

Chemistry and Stoichiometric calculation, thermodynamic analysis and concept of adiabatic flame temperature; Combustion appliances for solid, liquid and gaseous fuels: working, design principles and performance analysis.

Emissions from fuel combustion systems

Pollutants and their generation, allowed emissions, strategies for emission reduction, Euro and BIS norms for emission, recent protocols

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: To understand the fuel combustion process.

CO2: Apply fundamental aspects of combustion related problem and an understanding on the combustion appliances.

Books and References

1. Fuels & Combustion by Sharma S.P. & Chander Mohan, Tata McGraw Hill Publishing Co. Ltd.
2. Fuels & Combustion by Sarkar Samir, Orient Longman.
3. Fuels and Petroleum Processing by Sharma, B. K, Goel publishing.

Couse Name :	**Waste Heat Recovery Systems**	
Course Code :	**EN-702**	
Course Type :	**Program Elective-I**	
Contact Hours/Week:	**4L**	Course Credits: **04**

Course Objectives

- To understand the design of waste heat recovery systems efficient power cycles and power generation system.
- To identify sources of energy loss and power saving.

Course Content

Energy Pattern

Patterns of energy use, Types of waste heat recovery, Assessment of waste heat recovery, Sources of waste heat, Quality of waste heat, High, Medium and Low Temperature Heat Recovery, Potential for energy conservation, Waste heat recovery from micro turbines, Waste Heat cogeneration.

Optimum use of Energy Devices

Optimum use of energy resources, total energy approach, Coupled cycles, Combined plants and Cogeneration systems, Heat Wheel, Heat Pipes, Economizer, Heat Exchanger, Heat Pump, Need for energy storage, thermal electrical, magnetic and chemical energy storage systems, Utilization of industrial waste heat, gas-to-gas, gas-to-liquid and liquid-to-liquid , Low Temperature Waste Heat Utilization

Heat recovery Systems

Heat recovery systems, Recuperators and regenerators, Heat pipes, Thermoelectric industrial waste heat analysis/characterization, waste heat recovery boilers, Creation of Electricity by Waste Heat Recovery, Fluidized bed heat recovery, Shell and tube heat exchangers, Prime mover exhausts, Incineration plants, heat pump systems, thermoelectric devices, Utilization of low grade reject heat from power plants, Calculation of Heat Losses, Case Studies.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Check energy and fuel consumption and a wastage in existing facilities through effective metering and cost analysis.

Books and References

1. Mechanical Sciences Engineering Thermodynamics and Fluid Mechanics by S Mukherjee, P Roy**,** Prentice Hall, India.
2. Stoichiometry and Process Calculations by Narayanan, B Lakshnikutty, KV Narayanan**,** PHI.
3. Electric Power Generation Transmission and Distribution by Singh, PHI.
4. Environmental Management by Bala Krishnamoorthy, PHI.
5. Environmental Engineering by Srinivasan,PHI.

Couse Name : **Energy Generation, Transmission and Distribution Systems** Course Code : **EN-703** Course Type : **Program Elective-I**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To provide complete knowledge of various power generation systems and power units
- To learn the fundamental knowledge of transmission lines, power losses and efficiency of transmission along with performance parameters involved in transmission and distribution systems

Course Content

Power Generation Introduction to power generating units/stations and their classification, Schemes and plant-layout of Thermal, Hydro, Nuclear and Non-conventional energy generation stations. Design, operation and analysis of steam power plant, performance monitoring and testing of power unit, heat rates, Power plant efficiency or performance optimization. Steam generators and its classification, Heat balance and efficiency calculation of steam generators; Brief introduction of Fluidized bed boilers, Steam turbines, condensers, feed water or condensate heater, cooling towers. Gas turbine power units, Joule or Brayton cycle, Efficiency of cycle, ways to improve efficiency of steam power plant and gas turbine power plant.

Electricity Generation systems Synchronous generator, working principles, operation, power angle characteristics, concept of infinite bus, excitation systems, dynamic analysis and modeling of synchronous machines, governing / controlling system of prime mover, power generation control

Power Transmission Power transformers, its role and importance, types of transformers, Transmission lines, losses encountered in power regulation and transmission, performance evaluation, active and reactive power and its compensation, AC transmission, HVDC transmission, Power Grids, Synchronization of power units, power stations, substations, skin proximity, Ferranti effects, corona phenomena, critical voltages and power loss,

Distribution systems Conductor sizes, Kelvin's law of performance evaluation, distribution in industrial and commercial buildings entrance terminology, substation and feeder circuit design considerations, distribution automation.

Course Outcomes

Upon successful completion of the course, the student will be able to

CO1: Design power plant components for a specific application

CO2: Able to discuss various power generation units their advantages and disadvantages

CO3: Prepare AC and DC distribution networks for necessary variable calculation

Books and References

1. Generation, distribution and utilization of electrical energy by C. L. Wadhwa, New age International.
2. Electrical power transmission system: Analysis and design, by Turan Gonen, John Wiley and Sons.
3. Thermal power technology by Dr. V. K. Sethi, Sudit Publication.
4. Power generation technology by Dr. V. K. Sethi, Sudit Publication.
5. Modern power system analysis by I. S. Nagrah and D. P. Kothari, Tata Mc Graw Hill.
6. Power system analysis by John Grainger and Willian Stevensor, Mc Graw Hill.
7. Elements of power system analysis by William Stevenson, Mc Graw Hill.

Couse Name : **Computational Fluid Dynamics** Course Code : **EN-704** Course Type : **Program Elective-II**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To impart the knowledge of governing equation for fluid flow & different turbulence models.
- To learn about the numerical methods used to solve the partial differential equation.

Course Content

Introduction

Motivation and role of computational fluid dynamics, Concept of modeling and simulation.

Governing Equations of Fluid Dynamics

Continuity equation, Momentum equation, Energy equation, Various simplifications, Dimensionless equations and parameters, Convective and conservation forms, Incompressible invisid flows Basic flows, Source panel method, and Vortex panel method.

Nature of Equations

Classification of PDE, General behaviour of parabolic, Elliptic and hyperbolic equations, Boundary and initial conditions.

Finite Difference Method

Discretization, Various methods of finite differencing, Stability, Method of solutions.

Finite Volume Method

Steady one-dimension convection and diffusion, Properties of discretization schemes, Various methods of finite volume scheme.

Turbulence Modelling

Turbulence, effect of turbulence on N-S equations, different turbulent modelling scheme.

Incompressible Viscous Flows

Stream function-vorticity formulation, Primitive variable formulation, Solution for pressure, Applications to internal flows and boundary layer flows.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Acquire knowledge of various types of fluid flow governing equations.

CO2: Acquire enough knowledge to design the engineering system using commercial computational code.

Books and References

1. Computer Simulation of Flow and Heat Transfer by Ghosdastidar, P. S., McGraw Hill.
2. Computational Fluid Dynamics an Introduction by Wendt, J. F., Springer-Verlag.
3. Computational Fluid Flow and Heat Transfer by Muralidhar, K. and Sundararajan, T., Narosa.
4. Computational Heat Transfer by Jaluria, Y. and Torrance, K. E., Taylor & Francis.
5. Numerical Heat Transfer and Fluid Flow by Patankar, S. V., Taylor & Francis.

Couse Name : **Materials for Energy Applications**
Course Code : **EN-705**
Course Type : **Program Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To understand the concept of energy materials for energy generation.
- To analyze the material design, related to photovoltaic cell and energy storage.

Course Content

Materials

Glazing materials, Properties and Characteristics of Materials, Reflection from surfaces, Selective Surfaces: Ideal coating characteristics, Types and applications, Anti-reflective coating, Preparation and characterization. Reflecting Surfaces and transparent materials, Types of Insulation and properties

Physics of Solar Cells

Intrinsic, extrinsic and compound semiconductors, Electrical conductivity, Density of electrons and holes, Carrier transport: Drift, diffusion, Absorption of light, Recombination process, Materials for Photovoltaic's Conversion, Si and Non-Si materials, crystalline, semi-crystalline, Polycrystalline and Amorphous materials, p-n junction: homo and hetero junctions, Metal-semiconductor interface

Technology for Si extraction

Purification, Method of doping and junction fabrication, Cell fabrication and metallization techniques: Preparation of metallurgical, electronic and solar grade Silicon, Production of single crystal Silicon: Procedure of masking, photolithography and etching, Design of a complete silicon, GaAs, InP solar cell.

Sensible Heat Storage Materials

Stratified storage systems, Rock-bed storage systems, Thermal storage in buildings, Earth storage, Energy storage in aquifers, Heat storage in SHS systems, Aquifers storage

Phase Change Materials

Selection criteria of Phase change, Materials use in Solar heating or cooling, Research Status

Piezoelectricity and Ferro electricity

Optical properties, Interaction of solids with radiation, Luminescence, Photoconductivity

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Apply the concept of materials required for energy storage and energy generation.

Books and References

1. Solar Thermal Energy Storage by HP Garg, D Reidel Publishing Co.
2. Mathematical Modeling of Melting and Freezing process by V Alexiades and AD Solomon, Hemisphere Publishing Corporation, Washington.
3. Chemical and Electrochemical Energy System by R Narayan, B Viswanathan, Universities Press.
4. Energy Storage Systems by B Kilkis and S Kakac(Ed), KAP, London.

Couse Name : **Energy Generation from Waste**
Course Code : **EN-706**
Course Type : **Program Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To enable students to understand of the concept of waste to energy.
- To learn about the best available technologies for waste to energy.
- To link legal, technical & management principles for production of energy from waste.

Course Content

Solid Waste Sources

Solid Waste Sources, types compositions and Properties, Municipal Solid Waste: Physical, chemical and biological properties , Waste Collection and transfer stations, Waste minimization and recycling of municipal waste, Segregation of waste, Size Reduction, Managing Waste, Status of technologies for generation of Energy from Waste.

Waste Treatment and Disposal

Aerobic composting, Furnace types and designs, Medical waste /Pharmaceutical waste treatment Technologies, Incineration, Environmental impacts, Measures to mitigate environmental effects due to incineration.

Land Fill method of Solid waste disposal

Land fill classifications, Types, methods and Siting consideration, Layout and preliminary design of landfills: Composition, characteristics, generation, movement and control of landfill leachate and gases, Environmental monitoring system for land fill gases.

Energy Generation from Waste

Bio-chemical Conversion: Sources of energy generation, Anaerobic digestion of sewage and municipal wastes, Direct combustion of MSW-refuse derived solid fuel, Industrial waste, Agro residues, Anaerobic Digestion: Biogas production, Land fill gas generation and utilization, Thermo-chemical conversion: Sources of energy generation, Gasification of waste using gasifiers, Briquetting, Utilization and advantages of briquetting, Case studies of Commercial Waste to Energy Plants , Present status (National and International) of Technologies for Conversion of Waste into Energy, Design of Waste to Energy Plants for Cities, small townships and villages.

Environmental benefits of Bio-chemical and Thermo-chemical conversion

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Apply the knowledge about the operation of waste to energy plants.
CO2: Analyze the various aspects of waste to energy plant.
CO3: Apply the knowledge in planning & operation of waste to energy plants.

Books and References

1. Energy from Waste - An Evaluation of Conversion Technologies by C Parker and T Roberts (Ed), Elsevier Applied Science, London.
2. Basics of Solid and Hazardous Waste Management Technology by KL Shah, Prentice Hall.
3. Waste Disposal in Engineered Landfills by M Datta, Narosa Publishing House.
4. Solid Waste Management in Developing Countries by AD Bhide, BB Sundaresan, INSDOC, New Delhi.

Course Name: **Fuel Cells and Hydrogen Energy**
Course Code: **EN707**
Course Type: **Program Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To provide comprehensive and logical knowledge of hydrogen production, storage and utilization.
- To learn the fundamental knowledge about various fuel cell technologies.

Course Content

Fuel Cells History, Working principle of fuel cells, Fuel cell thermodynamics, fuel cell electrochemistry - Nernst equation, Electrochemical kinetics, Butler-Volmer equation, performance evaluation of fuel cells, Types of Fuel Cells: AFC, PAFC, SOFC, MCFC, DMFC, relative merits and demerits.

Fuel cell characterization In-situ and ex-situ characterization techniques, I-V curve, frequency response analyses; Fuel cell system integration

Application of Fuel Cells Fuel Cell usage for domestic power systems, large scale power generation, Automobile, environmental analysis. Future trends in fuel cells, portable fuel cells, laptops, mobiles, submarines.

Introduction of hydrogen energy systems Properties of hydrogen as fuel, Hydrogen pathways introduction-current uses, general introduction to infrastructure requirement for hydrogen production, storage, dispensing and utilization, and hydrogen production plants

Hydrogen production processes Thermal-Steam reformation, thermo chemical water splitting, gasification-pyrolysis, nuclear thermal catalytic and partial oxidation methods. Electrochemical-Electrolysis, photo electro chemical method.

Hydrogen storage and safety Physical and chemical properties, general storage methods, compressed storage-composite cylinders, metal hydride storage, carbon based materials for hydrogen storage. Hydrogen safety aspects, backfire, pre-ignition, hydrogen emission NOx control techniques and strategies, Hydrogen powered vehicles.

Course Outcomes

Upon successful completion of the course, the student will be able to

CO1: Evaluate the performance of fuel cells under different operating conditions.
CO2: Select and defend appropriate fuel cell technology for a given application.
CO3: Design and develop suitable hydrogen storage system to be used along with fuel cell system.
CO4: Minimize environmental hazards associated with the use of hydrogen storage and fuel cell technology.

Books and References

1. Electrochemical Methods by A.J. Bard and L.R.Faulkner, John Wiley & Sons, Inc.
2. Principles of Fuel Cells by Xianguo Li, Taylor & Francis.
3. Fuel cell Systems Explained by James Larminie and Andrew Dicks, John Wiley & Sons, Inc.
4. Fuel Cells: From Fundamentals to Applications by S Srinivasan, Springer.
5. Fuel Cell Fundamentals by O'Hayre, SW Cha, W Colella and FB Prinz, Wiley.
6. Fuel Cell Science and Technology by Basu, S. (Ed) Springer, N.Y.

Couse Name :	**Energy Storage Systems**	
Course Code :	**EN-708**	
Course Type :	**Program Elective-III**	
Contact Hours/Week:	**4L**	Course Credits: **04**

Course Objectives

- To study details of various energy storage systems along with applications
- Enabling to identify the optimal solutions to a particular energy storage application/utility

Course Content

Introduction: Necessity of energy storage, different types of energy storage, mechanical, chemical, electrical, electrochemical, biological, magnetic, electromagnetic, thermal, comparison of energy storage technologies

Energy Storage Systems: Thermal Energy storage, sensible and latent heat, phase change materials, Energy and exergy analysis of thermal energy storage, Electrical Energy storage-super-capacitors, Magnetic Energy storage-Superconducting systems, Mechanical-Pumped hydro, flywheels and pressurized air energy storage, Chemical-Hydrogen production and storage, Principle of direct energy conversion using fuel cells, thermodynamics of fuel cells, Types of fuel cells, AFC, PEMFC, MCFC, SOFC, Microbial fuel cell, Fuel cell performance, Electrochemical Energy Storage- Battery, primary, secondary and flow batteries,

Design and Applications of Energy Storage: Renewable energy storage-Battery sizing and stand-alone applications, stationary (Power Grid application), Small scale application-Portable storage systems and medical devices, Mobile storage Applications- Electric vehicles (EVs), types of EVs, batteries and fuel cells, future technologies, hybrid systems for energy storage.

Course Outcomes:

Upon successful completion of the course, the student will be able to

CO1: Understand need of energy storage systems

CO2: Acquire knowledge pertaining to various ways to store energy, its analysis and use

CO3: Focus and develop hydrogen storage and fuel cell systems though research

Test/References:

1. Energy Storage - Technologies and Applications by Ahmed Faheem Zobaa, InTech.
2. Fundamentals of Energy Storage by J. Jensen and B. Sorenson, Wiley-Interscience, New York,
3. Handbook of battery materials by C. Daniel, J. O. Besenhard,Wiley VCH Verlag GmbH & Co. KgaA
4. Electric & Hybrid Vehicles by G. Pistoia, Elsevier B. V.
5. Thermal energy storage: Systems and Applications by Dincer I. and Rosen M. A., Wiley pub.
6. Energy Storage: Fundmentals, Materials and Applications, by Huggins R. A., Springer
7. Fuel cell Fundamentals by R. O'Hayre, S. Cha, W. Colella and F. B. Prinz, Wiley Pub.
8. Chemical and Electrochemical Energy System by R. Narayan and B. Viswanathan, University Press.
9. Battery Systems Engineering by C. D. Rahn and C. Wang, Wiley Pub.
10. Electrochemical Energy Storage for Renewable sources and grid balancing by P. T. Moseley and J. Garche, Elsevier Science
11. Compressed air energy storage by F. P. Miller, A. F. Vandome, M. B. John, VDM publishing.

Couse Name	:	**Computational Heat Transfer in Energy Systems**
Course Code	:	**EN-709**
Course Type	:	**Program Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To study computational aspects of heat transfer
- Enabling students to anticipate outcome with the help of computations approach.

Course Content

Introduction: Physical Phenomena, Governing Differential Equation, Energy Equation, Momentum Equation, Nature of Co-ordinates, Discretization Methods, Parabolic Equations, Explicit, Implicit and Crank Nicholson Methods. Matrix Algaebra, Gaussian elimination.

Finite Element Method: Approximate Analytical Solution, Raleigh's Method, Galerikin Method, Solution Methods, Types of elements or meshes, One dimensional steady unsteady problems, two dimensional problems, Two dimensional Axisymmetric and Isoparametric Elements formulation and integration, Formulations of 1D, 2D heat conduction and diffusion Equations, incompressible inviscid flow (potential flow), and viscous incompressible fluid flow.

Course Outcomes:

Upon successful completion of the course, the student will be able to

CO1: Estimate outcomes of any physical situation using computational aspects of heat transfer

CO2: Gain confidence is adopting finite element approach for energy system analysis

CO3: Apply finite element method to many related thermal energy systems

Test/References:

1. Numerical Heat Transfer and Fluid Flow by Suhas V.Patnakar, Hemisphere Publishing Corporation.
2. Computational Heat Transfer by Jaluria and Torrance, Hemisphere Publishing Corporation.
3. Finite Difference Method in Partial Differential Equations by R. Mitchell and D.F. Grifths, John Wiley & Sons.
4. Introduction to Finite Elements in Engineering by Tirupathi R. Chandrupatle, Ashoka D. Belegundu, Prentice Hall.
5. An Introduction to Finite Element Method by J.N. Reddy, Mc Graw Hill.

Couse Name : **Modelling and Simulation** Course Code : **EN-710** Course Type : **Program Elective-IV**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To understand the design and simulation of the heat transfer equipments.
- To understand the numerical optimization of the systems utilized for the energy systems.

Course Content

Conventional energy technologies

Overview of technologies and conventional methods of energy conversion, Workable and optimum systems, Steps in arriving at a workable system, Creativity in concept selection

Mathematical modeling of heat transfer devices

Mathematical modeling, Exponential forms- Method of least squares - Counter flow heat exchanger, Evaporators and Condensers, Effectiveness, NTU, Pressure drop and pumping power

Numerical methods and modeling

Classes of simulation, flow diagrams, Sequential and simultaneous calculations, Newton- Raphson method-Optimization procedure, mathematical statement of the problem The Lagrange multiplier equations, Sensitivity coefficients- Single variable– Exhaustive, Dichotomous and Fibonacci, Multivariable unconstrained- Lattice, Univariable and Steepest ascent Dynamic Programming-Geometric Programming-Linear Programming- Linear regression analysis, Internal energy and enthalpy, Pressure temperature relationship at saturated conditions.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Apply various numerical methods for the optimization of the systems.

Books and References

1. Design of Thermal Systems by W.F. Stoecker, McGraw Hill.
2. Analysis and Design of Thermal Systems by B.K.Hodge, Prentice Hall Inc.

Couse Name : **Nuclear Power Technology**
Course Code : **EN-711**
Course Type : **Program Elective-IV**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To understand the concept of nuclear energy & nuclear fuels.
- To understand the working of nuclear reactors, polices & regulations required for the nuclear power plants.

Course Content

Basic Nuclear Concepts
Atomic Structure, Nuclear models, Equivalence of mass and energy, binding energy, Radio activity, half-life, mechanism of nuclear fission and fusion, decay chains, critical mass and composition, neutron reactions.

Nuclear Fuels
Nuclear fuel reserves of Uranium and Thorium, Nuclear fuel cycles, characteristics, production and purification, other fuels Zirconium, Beryllium**,** Reprocessing of nuclear fuels, Thorium Utilization in India.

Nuclear Reactors
Nuclear reactors and classification, boiling water reactors (BWR), pressurized heavy water reactor (PHWR), fast breeder reactor (FBR), basics of nuclear fusion reactor.

Nuclear Power Plant -Waste Management and Safety
Nuclear Power Plant, Nuclear power plant safety systems, Nuclear Accidents- consequences– case study, criteria for safety, Nuclear Waste management, International Convention on safety aspects, radiation hazards and their prevention.

Nuclear Infrastructure in India
Department of Atomic Energy (DAE), NPCIL, AERB, BARC, Indian Nuclear Industry, Economics of nuclear power plants, peaceful use of nuclear energy.

Nuclear Policy and Regulations
Atomic Energy Act, India's Nuclear Energy Programme, Indian nuclear energy policy, International Atomic Energy Agency [IAEA] ,International Nuclear Energy Policies and Regulations, Weapons proliferation NPT, safe guards to prevent nuclear proliferation, Indian Nuclear deal and 123 agreement and present Status of International Nuclear Co-operation.

Nuclear Radiation Applications
Radiation processing of food and allied products, applications of radio isotopes in Industry and Agriculture, Industrial radiotracer applications in Ground water exploration, Desalination.

Course Outcomes
Upon successful completion of the course, the students will be able to
CO1: Understand the nuclear energy usage & applications.
CO2: Understand the merits and demerits of nuclear energy.

Books and References

1. Fundamentals of Nuclear Engineering by TJ Cannoly, John Wiley.
2. Introduction to Nuclear Reactor Theory by JR Lamarsh, Wesley.
3. Introduction to Nuclear Power by JG Collier and GF Hewitt, Hemisphere Publishing, New York.
4. Nuclear Reactor Engineering by S Glasstone and A Sesonske, Von Nostrand.

Couse Name : **Energy Management**
Course Code : **EN-712**
Course Type : **Program Elective-IV**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To bring out energy conservation potential & business opportunities across different user segments under innovative business model.
- To provide knowledge and skills about the energy management utilize for establishment.

Course Content

General Aspects

General Philosophy and need of Energy Audit and Management, Definition and Objective of Energy Management, General Principles of Energy Management, Energy Management Skills, Energy Management Strategy, Energy Audit: Need, Types, Methodology and Approach. Energy Management Approach, Understanding Energy Costs, Bench marking, Energy performance, Matching energy usage to requirements, Maximizing system efficiency, Optimizing the input energy requirements, Fuel and Energy substitution.

Procedures and Techniques

Data gathering: Level of responsibilities, energy sources, control of energy and uses of energy get Facts, figures and impression about energy/fuel and system operations, Past and Present operating data, Special tests, Questionnaire for data gathering, Analytical Techniques: Incremental cost concept, mass and energy balancing techniques, inventory of Energy inputs and rejections, Heat transfer calculations, Evaluation of Electric load characteristics, process and energy system simulation, Evaluation of saving opportunities: Determining the savings in Rs, Noneconomic factors, Conservation opportunities, estimating cost of implementation, Energy Audit Reporting: The plant energy study report-Importance, contents, effective organization, report writing and presentation.

Energy Policy Planning and Implementation

Key Elements: Force Field Analysis, Energy Policy-Purpose, Perspective, Contents and

Formulation. Format and Ratification, Organizing: Location of Energy Manager, Top Management Support, Managerial functions, Role and responsibilities of Energy Manager, Accountability. Motivating–Motivation of employees, Requirements for Energy Action Planning. Information Systems: Designing, Barriers, Strategies, Marketing and Communicating Training and Planning.

Energy Balance & MIS

First law of efficiency and Second law of efficiency, Facility as an Energy system, Methods for preparing process flow, Materials and Energy Balance diagram, Identification of losses, Improvements. Energy Balance sheet and Management Information System (MIS) , Energy Modeling and Optimization.

Energy Audit Instruments

Instruments for Audit and Monitoring Energy and Energy Savings, Types of instruments and Accuracy

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Obtain knowledge about energy policy, regulations & business practices.

CO2: Obtain knowledge on the energy balance sheets & management information system.

Books and References

1. Energy Management by W.R.Murphy, G.Mckay. Butterworths.
2. Energy Management Principles by C.B.Smith, Pergamon Press.