

## **M.Tech. (Energy Technology & Management)**

### **Eligibility conditions**

B.E/B.Tech. in any branch of engineering/technology

M.Sc. in Physics or Chemistry with Mathematics at graduation level.

**Number of seats: 20**

### **Syllabus for TU Entrance Examination:**

The entrance examination will be assessing the awareness and exposure level of the student in the following subject areas:

Analytical, quantitative and verbal aptitude; Energy resources (conventional and new/renewable); Earth and solar radiation; Units and conversions; Thermodynamics and heat transfer; Materials and energy balance; Fluid mechanics and fluid machinery; Fuels and combustion; Energy conversion technologies; Steam; Hydrogen fuel; Energy storage; Electricity and power systems; Energy crisis; Energy and environment; Energy, global warming and climate change; Energy policy and legislation; Energy conservation and management.

## M.Tech. Energy Technology & Management

### Program Objectives

- To prepare the students for successful career in the energy industry; energy regulation and management agencies; and in the academic and R&D institutions.
- To produce graduates strong in energy resources, technologies and management fundamentals, and capable in addressing the present and potential future energy problems.
- To produce energy professionals, who are sensitive to, and well aware of, the energy issues and concerns, and who can apply their specialized knowledge for the sustainable energy management.

### First Semester

S. No.	Course No.	Course Title	L	T	P	Cr
1.	PEN 101	Thermodynamics and Heat Transfer	3	1	2	4.5
2.	PEN 102	Fluid Mechanics and Fluid Machinery	3	1	2	4.5
3.	PEN 103	Energy, Environment and Climate Change	3	1	0	3.5
4.	PEN 104	Energy Policy and Legislation	3	0	0	3.0
5.	PEN 105	Conventional Energy Technologies	3	1	2	4.5
6.	PEN 106	Renewable Energy Technologies -1	3	1	2	4.5
		<b>Total</b>	<b>18</b>	<b>5</b>	<b>8</b>	<b>24.5</b>

### Second Semester

S. No.	Course No.	Course Title	L	T	P	Cr
7.	PMA102	Research Methodology	2	0	2	3.0
8.	PEN201	Renewable Energy Technologies -2	3	1	2	4.5
9.	PEN202	Electrical Power Systems and Energy Management	3	1	0	3.5
10.	PEN203	Energy Conservation and Management	3	1	2	4.5
11.		Elective-1	3	1	2	4.5
12.		Elective-2	3	1	0	3.5
		<b>Total</b>	<b>17</b>	<b>5</b>	<b>6</b>	<b>23.5</b>

<b>Elective -1</b>		
2.1	PEN204	Hydrogen Fuel and Fuel Cell Technology
2.2	PEN205	Bio-energy and Technologies
2.3	PEN206	Solar Energy and Technologies
<b>Elective -2</b>		
2.4	PEN207	Energy Management Systems and Auditing
2.5	PEN208	Electrical Energy and Management
2.6	PEN209	Thermal Energy and Management

### Third Semester

S. No.	Course No.	Course Title	L	T	P	Cr
1.	PEN301	Seminar	-	-	-	2.0
2.	PEN302	Minor Project	-	-	-	4.0
3.	PEN091	Dissertation (Starts)	-	-	-	-

### Fourth Semester

Sr. No.	Course No.	Course Title	L	T	P	Cr
1.	PEN 091	Dissertation	-	-	-	12

**Total Number of Credits: 66.0**

### Program Outcomes (POs)

- Understood and acquired fundamental knowledge on the science of energy and on both the conventional and non-conventional energy technologies
- Acquired the expertise and skills needed for the energy monitoring, auditing and management, and for the development, implementation, maintenance and auditing of Energy Management Systems
- Become capable of analysis and design of energy conversion systems
- Acquired skills in the scientific and technological communications, and in the preparation, planning and implementation of energy projects

## PEN101 THERMODYNAMICS AND HEAT TRANSFER

L	T	P	Cr
3	1	2	4.5

### Course Objectives:

- To understand basic principals in thermodynamics and heat transfer, and developing an intuitive understanding of thermal sciences by emphasizing the physical arguments.
- To make student familiar with basic concepts, devices and properties used in thermal science with concepts of work, heat transfer and power in processes
- To make students familiar with how various engines and refrigerators function with application of process knowledge to the analysis of complete systems

**Introduction:** Energy and entropy balances, Equilibrium criteria; Chemical potential; Fugacity; Activity; Raoult's Law; Fugacities in gas mixtures; Virial equations of state; Fugacities in liquid mixtures; Ideal solutions; Excess functions; Gibbs-Duhem equation.

**Laws of thermodynamics and cycles:** Review of laws of thermodynamics; Conservation of Energy; Heat Capacity and definition of enthalpy; Reference and standard states;; reversible and irreversible processes; Entropy; Thermodynamics power cycles; Carnot cycle; Rankine cycle; Otto cycle; Diesel cycle; Vapor compression cycle; Power cycle; Brayton cycle.

**Material and energy balance:** balances and flowcharts; material balances with and without chemical reactions; open and closed system energy balance

**Conduction heat transfer:** Basic concepts of Conduction; Heat diffusion equations; Heat transfer laws; Heat Transfer through wall; cylinder; sphere; optimum thickness of insulation; Conduction with heat source; Unsteady state heat transfer.

**Convection heat transfer:** Boundary layers concept; Dimensionless numbers; various equations related to heat transfer during laminar and turbulent flow for flat plate as well as pipe flow; Convection with phase change; Condensation and boiling.

**Radiation heat transfer:** Radiation heat transfer basic laws; shape factor; shape factor calculations for different bodies; radiations exchange between surfaces.

**Heat exchangers and evaporators:** General design considerations of shell and tubes of heat exchangers and double pipe heat exchangers; thermo -physical properties; tube-side heat transfer coefficient and pressure drop; shell-side heat transfer coefficient and pressure drop; LMTD; effectiveness-NTU methods; Fouling and its effects; Single effect and multiple effect evaporators (MEE)

**Laboratory Work:** Heat transfer through composite wall; Thermal conductivity of lagging material on pipe / metal rod, sphere; Performance of parallel flow/counter flow heat exchanger; Drop wise & film wise condensation; Verification of Stefan Boltzmann's law of radiation; Heat transfer in natural convection; Heat transfer in forced convection.

### Course Outcomes

- Identify physical setup, find process and compute associated work/heat transfer that is the most reasonable approximation.
- For a given physical device and process, compute the work and heat transfer and formulate the ideal approximation to the behaviour.
- Apply principles of heat transfer to basic engineering systems with understanding of how processes affect the environment.
- Analysis and design of heat exchangers, evaporators with aim to improve their performance and economy

### Recommended Books

1. Nag PK, *Engineering Thermodynamics, Tata McGraw Hill (2008) 3rd ed.*
2. Sonntag RE, Borgnakke C and Van Wylen GJ, *Fundamentals of Thermodynamics, John Wiley (2007) 6th ed.*

3. *Smith JM, van Ness H and Abbott M, Introduction to Chemical Engineering Thermodynamics, McGraw-Hill (2001)*
4. *Holman JP, Heat Transfer, McGraw-Hill (2004), 9th ed.*
5. *Kern DQ, Process Heat Transfer, International Student Edition, Tata McGraw-Hill (2002).*

## PEN102 FLUID MECHANICS AND FLUID MACHINERY

L	T	P	Cr
3	1	2	4.5

### Course Objectives:

- To provide comprehensive understand of the basic concepts of fluid mechanics.
- To understand the principle, operation, construction and functioning of hydraulic machines.
- To understand the applications of fluid systems.

**Introduction:** Basic properties of fluids, Hydrostatics, Fluid Kinematics, Scope of Fluid Mechanics and Machinery

**Fundamentals of fluid flow:** Types and description of fluid flow pattern, continuity equation, rotational and irrotational motions, circulation and vorticity, streamlines and equi-potential lines, motion and energy equations-Bernoulli's equation, Euler equations, impulse-momentum equation. Dimensionless number and significance.

**Boundary layer theory and internal Flow:** Boundary layer equations for external flows-displacement, momentum and energy equations flow through pipes, losses and energy gradient.

**Fluid measurement:** Pressure measurements, Pitot tube, orifices and mouthpieces, venturimeter, rotameter, orifice meter, notches and weirs, water current meter, head loss calculations.

**Open channel flow:** Classification, discharge measurement, most economical sections, hydraulic jump and significance.

**Compressible flow:** Introduction, Thermodynamic relations, basic equation of compressible flow, Velocity of sound or pressure wave in a fluid, mach number, static and stagnation properties, area velocity relationship for compressible flows, flow of compressible fluid through orifices, venturimeter, pitot static probes.

**Hydraulic turbine:** Impacts of jets, forces exerted by jets on vertical and hinged plates, forces exerted on curved plates, classification and types of turbines, Velocity triangle and work output for impulse turbines, axial and radial flow reactions turbines, draft tube theory, cavitations, operational characteristics of hydraulic turbines, specific speed of turbines.

**Hydraulic pumps:** Pump classifications, Pumps in series and multistage, pumps efficiencies and pump losses, NPSH, pump operating characteristics, pump selection and pumping stations. Fans and blowers.

**Fluid systems:** Introduction, Hydraulic press, hydraulic accumulator, hydraulic ram, hydraulic lift and crane, hydraulic couplings, torque convertor, air lift pump, gear-wheel pump.

**Laboratory Work:** Verification of Bernoulli's equation, calibration of notches, venturimeter, orifice-plate, determination of friction factor for pipes, verification of momentum equation, Performance characteristics of pumps, , Performance characteristics of turbines, Hydraulic ram.

### Course Outcomes:

- Acquiring scientific and technological understanding on the different aspects of fluid flow.
- Gaining skills to calculate head losses in different fluid flow measurement devices.
- Ability to design the hydraulic machines and its selection criteria.

### Recommended Books

1. Bansal RK, *Fluid Mechanics and Hydraulics Machines*, Luxmi Publishers (2010)
2. Fox RW, McDonald AT and Pritchard PJ, *Introduction to Fluid Mechanics*, Wiley & Sons Inc, (2008)
3. Cengel YA, *Fluid Mechanics*, McGraw-Hill (2008)

## PEN103 ENERGY, ENVIRONMENT AND CLIMATE CHANGE

<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>
<b>3</b>	<b>1</b>	<b>0</b>	<b>3.5</b>

### Course Objectives:

- To understand the interrelationship of energy and environment.
- To know the impacts of energy systems on environment.
- To know the basic concepts of climate change and strategies for conservation of environmental changes.

**Overview:** Introduction, Role of energy in economic development and social transformation: Energy and GDP, GNP and its dynamics, Impact of Energy on Economy, Energy Sources and overall energy demand and availability, Energy Consumption in various sectors and its changing pattern, Energy Security: Chemical and Nuclear: Non Proliferation, Future Energy Options: Sustainable Development, Energy Crisis : Transition from carbon rich and nuclear to carbon free technologies.

**Energy and environmental policies:** Environmental implication of energy use, CO<sub>2</sub> emission in atmosphere, Development and Environment, Need for use of new and renewable energy, Energy Policy Issues: Fossil Fuels, Renewable Energy, Power sector reforms, restructuring of energy supply sector, energy strategy for future sources.

**Environmental impacts of energy technologies:** Limitations of traditional energy technologies, criteria for the selection of new energy sources, Environmental degradation due to energy production and utilization, fallout from nuclear explosions – fuel processing and radioactive waste, Radioactivity risk assessment, biological damage due to environmental degradation, Methods of Environmental Impact Assessment, Effect of Hydro electric power stations on ecology and environment.

**Global climate change:** Elements of climate, Climatic classifications, climatic controls, Spatial and temporal patterns of climate parameters in India. Indian monsoon jet streams, general circulation and urban climatology. Causes and consequences of Global Warming, Ozone hole and consequence of Ozone Depletion, Montreal Protocol, Kyoto protocol and recent conventions. Climatic considerations in Industrial locations, city planning, landscape architecture and abatement/mitigation of pollution, Strategies for Conservation of Environmental Changes induced by CO<sub>2</sub> Rise, the concept of Carbon Sequestration. Clean Development Mechanism (CDM) and its operationalization, modalities and procedures for CDM Project. Renewable energy certifications, renewable purchase obligations, Automobile Emissions, Indian Scenario, Impact of Automobile Pollutants and its Abatement.

### Course Outcomes:

- Acquiring scientific and technological understanding on the energy and associated environmental issues.
- Get acquainted with the environmental impacts of energy technologies.
- Knowing the issues related to climate change, related protocols and modalities as well as procedures for CDM projects.

### Recommended books:

1. *Brown CE, World Energy Resources : Charles E. Brown, Springer (2002).*
2. *Tiwari GN, Renewable Energy Resources: Basic Principles and Applications Narosa Publishing House (2005).*
3. *Dayal M, Renewable Energy Environment and Development, Konark Publishers Pvt. Ltd (1998).*

## PEN104 ENERGY POLICY AND LEGISLATION

L	T	P	Cr
3	0	0	3.0

### Course Objectives:

- To provide an intensive introduction to the basic perspectives; processes and institutions; major developments in the environmental policy of the country; environmental regulations associated with energy policy and recent innovations; and implications of emerging national issues and institutions.
- To develop student's skills in critical thinking and reasoning about policy issues associated with various industrial sectors.

**Definitions of terms:** Conventions, protocols, policy, law, act and rule, administrative and legal interpretations, codes and specifications.

**Overview:** Energy scenario of India; Key energy concerns and issues – Carbon emissions, meeting the growing energy demands and providing access to everyone and protecting the poor, Pricing mechanisms and producer and consumer subsidies, Energy imports and import dependence of India; Overview of energy legislation of India; Overview of energy policies and plans of the Govt. of India.

**Energy sectors, departments and ministries of India:** Power sector and Ministry of Power; Coal sector and Ministry of Coal; Oil & gas sector and Ministry of Petroleum and Natural Gas; Renewable Energy sector and Ministry of New and Renewable Energy; Nuclear sector and Department of Atomic Energy; Bureau of Energy Efficiency; International Energy Agency.

**Key energy acts and rules made there under:** The energy conservation Act, 2001; The Electricity Act, 2003; The Atomic energy Act, 1962; The Coalmines (conservation & development) Act, 1974; Other legislation concerning power, coal, oil & gas, renewable energy, nuclear energy sectors.

**Institutional structures of energy administration in India:** ONGC, State Electricity Boards; Atomic Energy Agency, etc.

**Energy policies and plans:** Integrated energy policy, 2008; National policy on bio-fuels; Strategic plan for new and renewable energy sector for the period of 2011-2017; 5 year plans and their impacts on energy sector; National action plan for climate change.

**Energy management systems:** ISO 50001: 2011.

### Course Outcomes:

- Gaining appropriate knowledge on various policies and legislations associated with energy administration.
- Gaining awareness on policies that facilitate development of energy conservation strategies and methods.
- Becoming aware of the Energy Acts and of the legal energy requirements applicable to the various industrial sectors.

### Recommended books

1. *India: Energy policy, laws and regulations handbook, Volume-1: Strategic information and renewable energy. International business publications, USA. 2010.*
2. *Naseem M, Energy Law in India, Kluwer Law International BV, The Netherlands (2011).*



## PEN105 CONVENTIONAL ENERGY TECHNOLOGIES

L	T	P	Cr
3	1	2	4.5

### Course Objectives:

- This course will enable to understand combustion phenomenon and thermal analysis of steam, gas, nuclear and combined cycle power plants.
- To facilitate clear understanding of these technologies to be able to select an appropriate type of plant for given requirements under different situations.
- To develop skills to select suitable components and equipments and to understand the operation of these plants/equipments.

**Fuels and combustion:** Introduction, Fossil fuels & its resources, Fuel properties & storage, classification of coal, use of high ash coal, lignite coal, drying, storage and handling of coal and liquid fuels, types of mills, types of petroleum fuels, fuel firing, furnace construction, grates, pulverisers, oil & gas burners and fluidized bed combustion system, combustion equations (stoichiometric and non-stoichiometric), analysis of products of combustion, conversion of volumetric and gravimetric analysis.

**Thermal energy:** Thermal energy and thermal power stations; Vapour power cycles; Fuels and Combustion; Fuel handling systems; Ash handling; Types of boilers; High-pressure boilers, Super critical boilers; Boiler systems; Super heaters, Reheaters, Economizers, Air Preheaters, heat recovery units, Pumps and Fans, etc.

**Boiler feed water and steam:** Treatment and conditioning of boiler feed water; DM water, soft water and RO water plants; Degasifiers and Deaerators, Conditioning of cooling waters; Steam and steam properties; Steam calculations; Pressure reducing systems.

**Turbines:** Steam turbines – types and classification: Steam nozzles; Governing; Turbine losses and turbine efficiencies; Condensers and cooling towers; Cogeneration and back-pressure turbines; trigeneration, polygeneration, overall heat rate, Gas Turbines - types and classification; Combined cycle power plant and analysis; IGCC plant and binary vapour cycles; Internal combustion engine based power plants - DG sets.

**Nuclear energy:** Nuclear energy – potential, challenges and opportunities; Nuclear fuels; Nuclear fusion and fission technologies; Breeder technology; Nuclear fuel enrichment, nuclear reaction control.

**Nuclear reactors:** Components of nuclear reactors, fuel cladding, moderators, coolants, control rods, Nuclear reactors and types - PWR, BWR, Fast Breeder Reactors; Recent developments in nuclear reactors Nuclear wastes and their management - spent fuel, reprocessing of waste, and low-level radioactive waste; Reactor safety and safety measures.

**Hydropower:** Importance and potential of hydro-electric power; Hydropower - merits and demerits; Types of hydroelectric power plants; Run-of-the-river power plants.

**Hydroelectric power plants:** Power houses and underground power houses; Components of a hydroelectric power plant; Intakes – penstocks; Hydraulic prime movers; Classification of modern water turbines; Draft tube theory; Cavitation; Torque - power and efficiency; Performance characteristics; Specific speed characteristics; Power house safety requirements.

**Laboratory Work:** Field visit of thermal plant, determination of dryness fraction, cooling tower, evaluation of brake power, brake thermal efficiency, brake specific fuel consumption and heat balance sheet.

### Course Outcomes:

- Ability to identify, track and solve various combustion problems and evaluate theoretically the performance of various components involved in thermal power plants.
- Gaining appropriate knowledge on principal of operation, construction and working of power plants equipment and components.

- Becoming aware of the appropriate technologies used in the power plants and integration of the thermal energy management system.

***Recommended Books***

1. *Wakil M, Power Plant Engineering, McGraw Hill. (2004)*
2. *Nag PK, Power Plant Engineering, Tata McGraw Hill Ltd. (2010)*
3. *Bansal PK, Fluid Mechanics & Hydraulic Machines, Luxmi Publishers, (2012)*

## PEN106 RENEWABLE ENERGY TECHNOLOGIES -I

L	T	P	Cr
3	1	2	4.5

### Course Objectives:

- To provide an understanding of solar energy systems and wind energy resources, with scientific examinations of the energy field and emphasis on their technology and applications.
- To facilitate development of skills to formulate waste to energy appropriate technologies in industrial applications.

**Overview of new and renewable energy resources:** Renewable and non-conventional energy resources; Introduction to renewable energy technologies; CDM and sustainable energy; Direct energy conversion devices-Thermionic, thermoelectric, MHD generator, Fourth generation energy systems.

**Solar energy:** Solar radiation, components and spectral distribution; Sun-earth geometry and basic earth-sun angles; Factors governing availability of solar energy on the earth; Estimation of average daily global solar radiation; Radiation instruments and radiation measurement – pyranometers and pyrhemometers; Global solar energy balance and earth's energy budget; Fate of solar radiation in the atmosphere and on the earth.

**Solar energy collectors:** Stationary collectors – flat plate collectors, compound parabolic collectors and evacuated tube collectors; Sun tracking concentrating collectors – parabolic trough collectors, Fresnel collectors, parabolic dish reflectors, Heliostat filled collectors.

**Solar energy applications:** Passive and active solar water heating systems; Solar space heating and cooling; Solar buildings; Green houses; Solar cooling by adsorption systems, absorption systems and by absorption refrigeration systems; Solar cookers and solar driers; Solar desalination systems - direct and indirect collection systems.

**Solar thermal power systems:** Solar thermal power generation schemes; Parabolic trough solar power generating systems; Central receiver power plants (solar power towers); Solar chimney power plants; Dish sterling systems; Solar ponds, Thermal analysis of solar power plants.

**Photovoltaic systems:** Semiconductors; Photovoltaic panels; Types of photovoltaic technologies; Equipment related to photovoltaic technology – batteries, invertors, charge controllers, maximum power point tracking; size of PV system, PV applications, Design of photovoltaic systems; Concentrating photovoltaic systems; Hybrid photovoltaic/thermal systems.

**Wind energy basics:** Potential of Wind energy in India; Wind energy developments in India; Wind energy resources - assessment and selection of prospective wind energy sites. Wind farms; Environmental impact of wind turbine power plant; Wind diesel hybrid systems; Solar-wind hybrid systems; Wind pumps; Environmental impacts of wind farms.

**Wind energy technologies and design:** Wind energy conversion technologies and types; Wind turbine technology developments; Turbine components and performance; Design of wind turbine; Control systems; Planning and design of wind farms; Feasibility study and technology assessment – cost benefit analysis of wind energy projects; Installation and commissioning of WECS; Grid integration of WECS.

**Laboratory Work:** Performance characteristics of solar flat plate collector, parabolic collector, solar stand PV system, solar water heating system, wind turbine system, field visits.

### Course Outcomes:

- Gaining appropriate knowledge on principles of operation, construction and working of solar photovoltaics and solar thermal devices.
- Ability to design solar thermal and wind energy conversion system for appropriate applications.

- Gaining comprehensive knowledge of how performance of solar and wind energy can be evaluated.

***Recommended Books***

1. *Goswami DY, Krieth F and Krieder JF, Principles of Solar Engineering, second edition, , Taylor and Francis Inc. (2000)*
2. *Tiwari GN, Solar Energy, , Narosa Publisers, (2002) 2<sup>nd</sup> Ed.*
3. *Garg HP and Prakash J, Solar Energy – Fundamentals and Applications, Tata McGraw-Hill, (2004)*
4. *Lee S, and Shah YT, Biofuels and Bioenergy: Process and Technology, Earthscan (2009).*

## PMA102 RESEARCH METHODOLOGY

L	T	P	Cr
2	0	2	3.0

### Course Objectives:

- Ability to elaborate the concept of distribution function
- Ability to distinguish between a discrete and continuous random variable and discuss transformation of one-dimensional, two-dimensional variables
- Develop potential towards problem solving using analysis of variance techniques
- Able to compute and interpret Karl Pearson's correlation coefficient and Spearman's rank correlation coefficient
- Able to constitute random block design, Latin square design, and derive their probability distributions

**Introduction:** Nature and objectives of research, Study and formulation of research problem, Scope and formulation of hypothesis, Preparation and presentation of research and project proposals, Selection of thrust research.

**Introduction to Statistical Analysis:** Measures of Central Tendency and Dispersion, Mean, Median, Mode, Range, Mean deviation, Standard Deviation.

**Random Variables and Probability Distribution:** Definition, Distributions, Functions, Mathematical Expectation, Binomial, Poisson, Geometric, Negative binomial, Exponential, Normal and log-normal distributions.

**Hypothesis Testing:** Tests of Significance based on normal, t and chi-square distributions, Analysis of variance technique.

**Linear Regression and Correlation:** Linear regression, Least square principle and fitted models, Karl Pearson's correlation coefficient, Rank Correlation, Lines of regression.

**Design of Experiments:** Completely randomized design, Random block design, Latin square design, Statistical analysis and variances of estimates, Analysis of covariance.

**Laboratory Work:** Implementation of statistical techniques using statistical packages *viz.*, SPSS, Mathematica including evaluation of statistical parameters and data interpretation, Regression Analysis, Covariance, Hypothesis testing and analysis of variance.

### Course Outcomes:

- Acquiring skills for formulating research problems and hypotheses to be tested, and for the preparation and presentation of research/project proposals.
- Obtaining the knowledge of probability and data distribution functions and becoming capable of estimating mathematical expectations.
- Acquiring the skills of regression and correlation analysis, development of statistical models, and calibration, validation and use of the models.
- Becoming capable of design of experiments for investigations and hypotheses testing relating to research problems and projects.
- Getting acquainted with the commercially available software packages for the statistical data analysis.

### Recommended Books

1. Dowdy S, Wearden S and Chilko D. *Statistics for Research, Wiley Series (2004) 2<sup>nd</sup> ed.*
2. Walpole RE, Myers RH, Myers SL. and Ye K. *Probability and Statistics for Engineers and Scientists, Pearson Education (2002) 7<sup>th</sup> ed.*

## PEN201 RENEWABLE ENERGY TECHNOLOGIES-II

L	T	P	Cr
3	1	2	4.5

### Course Objectives:

- To provide knowledge, understanding and application oriented skills on wind, ocean, tidal and geothermal energy sources and relevant technologies towards their effective utilization for meeting energy demand.
- To develop clear understanding of these technologies to be able to select an appropriate type of plant for given energy requirements.

**Biomass energy:** Biomass energy resources – types and potential; Energy crops.

**Biomass energy technologies:** Biomass characterization (proximate and ultimate analysis); Biomass pyrolysis and gasification; Biomethanation and biogas plants; biogas enrichment and conditioning, Biofuels – biodiesel, bioethanol, Biobutanol; Algae and biofuels; Hydrolysis & hydrogenation; Solvent extraction of hydrocarbons; Pellets and briquets of biomass; Biomass based thermal power plants; Biomass as boiler fuel; Social, economic and ecological implications of biomass energy; Biomass fuels and GHG emissions.

**Waste to energy:** Agricultural residues and wastes including animal wastes; industrial wastes; municipal solid wastes; Incinerators, gasifiers and digestors; Land fill gases and leachates.

**Ocean wave and tidal energy:** Introduction to tidal and ocean wave energy; Potential sources in India; Understanding of wave and current movements for tapping of energy; Estimation of energy – Maximum and minimum power ranges; Different wave energy conversion devices; Principles of tidal power generation; Components of a tidal power plant; Current technologies and future challenges in the wave, tidal stream and barrage energy production; Coastal impacts of marine based energy.

**Ocean energy:** OTEC Principles and technologies; Lambert's law of absorption; Open cycle and closed cycle; Major problems and operational experience; Future scope, potential and assessment of ocean thermal energy sources and conversion technologies.

**Geothermal energy:** Geothermal energy sources – types and potential; Physico-chemical features of geothermal reservoirs; Direct and indirect uses of geothermal energy resources; Geothermal energy conversion technologies; Low temperature steam applications; High temperature geothermal power plants; heating, ventilation and air conditioning applications of geothermal energy sources; Environment impacts.

**Mini and micro hydel power plants:** Pumped storage power plants; Siting and design of mini and micro hydro power plants; Ecological and environmental concerns and impacts of hydro electric power.

**Unconventional energy resources:** Unconventional oil/gas resources, tar, shale gas, coal bed methane, Fourth generation energy systems.

**Laboratory Work:** Biogas operated dual fuel engine, soxhlet solvent oil extraction process, biodiesel production process, gasifier based dual fuel engine, methane production and anaerobic digestion process, pyrolysis, briquetting, field visits.

### Course Outcomes:

- Gaining knowledge on the operation, working and technological advances in wind, ocean, tidal, geothermal and mini/micro hydel power generation systems.
- Describe the challenges and problems associated with the use of biomass, ocean, tidal and geothermal energy sources and mini/micro hydel power with regard to the future supply and the environment.
- Discuss remedies/potential solution to the supply and environmental issues associated with the unconventional oil and gas energy resources.

### ***Recommended Books***

1. *Dickson MH, Geothermal Energy: Utilization and Technology, UNESCO (2005)*
2. *Charlier RH, Ocean Energy: Tidal and Tidal Power, R.H. Charlier, Springer-Verlag (2004)*
3. *Manwell JF and Roger AL, Wind Energy: Theory, Design and Applications, Wiley Inc., (2008)*
4. *Sorenson B. Renewable Energy, Elsevier (2010) 4<sup>th</sup> Ed.*
5. *Rao S, Parulekar BB. Energy Technology: Non-conventional, Renewable and Conventional, Khanna Pub.(2005) 3<sup>rd</sup> Ed.*
6. *Fay JA, Golomb DS. Energy and Environment, Oxford University Press (2002)*

## PEN202 ELECTRICAL POWER SYSTEMS AND ENERGY MANAGEMENT

<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>
<b>3</b>	<b>1</b>	<b>0</b>	<b>3.5</b>

### Course Objectives:

- To provide an intensive introduction to the transmission system, power factor correction and distribution losses.
- To introduce fundamentals of operation and control of power system, relaying and protection of transmission lines with emphasis on their technology and applications.
- To elucidate concepts on energy losses in transmission, distribution and energy saving by power factor correction.

**Transmission lines and cables:** Transmission line parameters, use of ACSR and bundled conductors, regulation, performance and transmission line losses, corona loss in transmission lines; coaxial cables, grading of cables, performance calculation and measurement, comparison between transmission lines and coaxial cables; supply systems, distribution systems, conductors size, Kelvin's law performance calculations and analysis.

**Power factor correction:** Concept of power factor and reactive power, causes and effects of low power factor, advantages of improved power factor, energy saving by power factor improvement through capacitor, synchronous generator and STATCOM, economic consideration for the design of compensator.

**Operation and control of power system:** Synchronous machine operation and capability analysis, governing systems, automatic generation control, automatic voltage regulator, hydro, steam, wind and gas turbine modelling, power system stabilizer, economic operation of thermal units.

**Power system harmonics and filters:** Problem of harmonics in power system, sources of harmonics, ac and dc side harmonics, computation and measurement of harmonics, performance measures, harmonic mitigation through passive and active filters.

**Relaying and protection and substation practices:** Fault calculation, circuit breakers, isolators, fuses and connectors, types of circuit breakers; relaying elements, relay types and characteristics, protection of transmission lines, transformer, generator and motor, numerical relays, grounding, earthing and metering.

### Course Outcomes:

- Gaining appropriate knowledge on various parameters of transmission lines and losses.
- Gaining awareness on power factor correction and energy saving by capacitor and STATCOM.
- Becoming aware of the operation and control of power system, power system harmonics and protection of transmission lines.

### Recommended Books:

1. Nagrath IJ and Kothari DP, *Power System Engineering*, Tata McGraw-Hill (2007).
2. Wadhwa CL, *Electrical Power Systems*, New Age International (P) Limited, Publishers (2008) 4<sup>th</sup> ed.
3. Gupta BR, *Power System Analysis and Design*, S. Chand (2009).
4. Pabla AS, *Electric Power Distribution*, McGraw Hill (2008).
5. Mukherjee PK and Chakravorty S, *Electrical Machines*, Dhanpat Rai (2004) 2<sup>nd</sup> ed.
6. Nagrath IJ and Kothari DP, *Electric Machines*, Tata McGraw Hill (2004) 3<sup>rd</sup> ed.



## PEN203 ENERGY CONSERVATION AND MANAGEMENT

<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>
<b>3</b>	<b>1</b>	<b>2</b>	<b>4.5</b>

### Course Objectives:

- To understand and appreciate the energy crisis and environmental concerns associated with the energy management, and the importance of energy conservation.
- To know the techniques of energy analysis and the associated energy efficient technologies for the routinely used thermal and electrical energy systems.
- To understand the energy management systems and their essential elements.
- To acquire the knowledge and the basic skills for energy monitoring, energy bench marking, energy action planning and energy auditing.

**Introduction:** Energy resources; New and renewable energy resources; Energy forms and energy technologies; Energy and environmental concerns; Energy scenario and energy crisis; energy resources management and energy conservation – principles; Potential areas industries; Agriculture and municipal for energy conservation; Conservation methods.

**Energy efficient technologies in thermal systems:** Fuels and combustion; Boilers and turbines; Cogeneration and combined cycles; DG sets; Circulating cooling water systems; Steam system and condensate systems and insulation; Heat exchangers; Multiple effect evaporations; Furnaces; Thermo-compressors and mechanical vapour compressors; Waste heat recovery and reuse.

**Energy efficient technologies in electrical systems:** Electrical motors and drives; Pumps; Fans and Blowers; Air compressors and compressed air systems; Buildings and space heating and lighting systems; HVAC systems.

**Energy management:** Supply side and demand side management; Energy conservation methods; Energy management systems; Energy monitoring; Energy review and energy bench marking; Energy action planning; Energy auditing.

**Energy policy and legislation:** Energy policy; Energy conservation act; 2001; Energy managers and energy auditors; Energy labeling and energy standards.

**Laboratory Work:** Energy Lens – Energy Management Software; and Energy Plus Energy Simulation software.

### Course Outcomes:

- Becoming aware of the energy crisis, and of environmental and sustainability concerns associated with the energy management.
- Appreciating the importance of energy conservation and having the knowledge of energy conservation strategies and methods.
- Understanding the Energy Management Systems (EnMS) and their essential elements.
- Becoming aware of the Energy Conservation Act, 2001, and of the legal energy requirements applicable to the routinely used thermal and electrical energy systems Aware.
- Exposure to the most used energy planning and management softwares.

### Recommended Books:

1. *Practical guide to energy conservation – a ready reckoner on energy conservation measures;* Petroleum Conservation Research Association (2009).
2. *Indian Energy Board-2012; World Energy Council.*
3. *Reay DA, Industrial energy conservation; Pergamon Press (1979).*
4. *White LC, Industrial Energy Management and Utilization; Hemisphere Publishers; (1988).*
5. *Eastop TD, Croft DR, Energy Efficiency for Engineers and Technologists; Longman and Scientific and Technical (1988).*

## PEN204 HYDROGEN FUEL AND FUEL CELL TECHNOLOGY

L	T	P	Cr
3	1	2	4.5

### Course Objectives:

- To provide a detailed introduction to hydrogen energy with reference to current uses, production routes, storage methods, utilization and applications.
- To provide knowledge on direct energy conversion fuel cells, working, performance evaluation and applications.
- To develop skills in critical thinking and reasoning about issues associated hydrogen fuel and fuel cell technology.

**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, Biological-Anaerobic digestion, fermentation micro-organism, PM based electrolyser.

**Hydrogen storage:** Physical and chemical properties, general storage methods, compressed storage-composite cylinders, glass micro sphere storage, zeolites, metal hydride storage, chemical hydride storage and cryogenic storage, carbon based materials for hydrogen storage, hydrogen as storage medium for renewable energy systems.

**Hydrogen utilization:** Overview of hydrogen utilization, IC Engines, gas turbines, hydrogen burners, power plant, refineries, domestic cooking gas, marine applications, industrial processes of hydrogen, hydrogen dual fuel engines.

**Fuel cells:** History – principle - working - thermodynamics and kinetics of fuel cell process – performance evaluation of fuel cell – comparison on battery Vs fuel cell, Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC, microbial fuel cells, relative merits and demerits.

**Applications of fuel cells:** 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, portable fuel cells, laptops, mobiles, submarines.

**Hydrogen safety:** Hydrogen safety aspects, backfire, preignition, hydrogen emission NO<sub>x</sub> control techniques and strategies, Hydrogen powered vehicles.

**Laboratory Work:** Hydrogen production via biological process, electrolysis, hydrogen operated SI and CI engine etc, field visits

### Course Outcomes:

- Gaining appropriate knowledge on hydrogen production technological route through fossil fuel and renewable resources.
- Gaining awareness on working, construction and performance evaluation of various fuel cells.
- Describe the challenges and problems associated with the use of hydrogen and fuel cell technology with regard to the safety aspects and the environment.

### Recommended Books:

1. Sorenson B, *Hydrogen and Fuel Cells: Emerging Technologies and Applications*, Bent Sorenson, Academic Press (2005).
2. Hordeski MF, *Hydrogen and Fuel Cells: Advances in Transportation and Power*, The Fairmont Press, Inc. (2009)
3. Busby RL, *Hydrogen and Fuel Cells: A Comprehensive Guide*, PennWell Books (2005)

## PEN205 BIO-ENERGY AND TECHNOLOGIES

L	T	P	Cr
3	1	2	4.5

### Course Objectives:

- Provide understanding of the processes for converting biomass feedstocks to fuels by various approaches.
- Gain potential to evaluate technological, economic and business dimensions of energy production from biomass.

**Biomass resources and biomass properties** – biomass – definition – classification – availability – estimation of availability, consumption and surplus biomass – energy plantations. Potential of biomass and assessment.

**Thermo chemical conversion:** Direct combustion, incineration, pyrolysis and gasification; Biomass stoves, improved chullahs and some exotic designs; Design, construction and operation of biomass combustors including incinerators; Biomass pyrolysis – types, manufacture of charcoal, manufacture of pyrolytic oils and gases; Design, construction and operation of pyrolysis units; Biomass gasification – types, gasifier burner arrangement for thermal heating, gasifier engine arrangement for electrical power; Design, construction and operation of gasifiers, biomass fired boilers and types.

**Biological conversion:** Biodegradation and biodegradability of substrate; Biochemistry and process parameters of biomethanation; Biogas digester types; Digester design and biogas utilisation; Chemical kinetics and mathematical modeling of biomethanation process; Economics of biogas plant with their environmental and social impacts; Bioconversion of substrates into alcohol: Methanol & ethanol Production, organic acids, solvents, amino acids, antibiotics etc.

**Chemical conversion:** Hydrolysis and hydrogenation; Solvent extraction of hydrocarbons; Bioethanol; Chemicals from biomass.

**Bio-diesel:** History, Production methods of Bio-diesel: Transesterification, Fuel quality, standards and properties, Availability of Raw materials for bio-diesel, Applications, Bio-diesel potential in India.

**Waste to energy** Introduction to Energy from waste - classification of waste as fuel – agro based, forest residue, industrial waste, MSW – conversion devices – incinerators, gasifiers, digestors, Environmental monitoring system for land fill gases, Environmental impacts; Measures of mitigate environmental effects due to incineration.

**Laboratory work:** Biogas operated dual fuel engine, soxhlet solvent oil extraction process, biodiesel production process, gasifier based dual fuel engine, methane production and anaerobic digestion process, pyrolysis, briquetting etc.

### Course Outcomes:

- Able to understand the challenges and problems associated with the use of various bioenergy sources with regard to future resource and the environment.
- Able to evaluate the cost-benefit of various biomass energy conversion processes.
- Able to identify remedies/potential solutions to the supply and environmental issues associated with biomass based energy resources.

### Recommended books:

1. Capareda S, *Introduction to biomass energy conversion*, CRC Press (2013).
2. Lorenzini G and Biserni C, *Solar Thermal and Biomass Energy*, WIT Press (2012).
3. Brown RC and Stevens C, *Thermo-chemical Processing of Biomass: Conversion into Fuels, Chemicals and Power*, Wiley and Sons (2011).

## PEN206 SOLAR ENERGY CONVERSION TECHNOLOGIES

L	T	P	Cr
3	1	2	4.5

### Course Objectives:

- To provide a detailed introduction to solar energy measurement techniques and harnessing solar energy potential through solar devices.
- To provide knowledge on working of solar photovoltaics and solar thermal devices performance evaluation and applications.
- To develop skills in critical thinking and reasoning about issues associated direct and indirect use of solar energy.

**Solar radiation and availability:** Introduction, Solar radiation, components and spectral distribution; Fate of solar radiation in the atmosphere and on the earth; Radiation instruments and radiation measurement – pyranometers and pyrhemometers; Sun-earth geometry and basic earth-sun angles; Solar time and equation of time; Duration of sunshine hours and angle of incidence of solar radiation; Factors governing availability of solar energy on the earth; Estimation of average daily global solar radiation.

**Solar energy collectors:** Stationary collectors – flat plate collectors, compound parabolic collectors and evacuated tube collectors; Sun tracking concentrating collectors – parabolic trough collectors, Fresnel collectors, parabolic dish reflectors, Heliostat filled collectors.

**Solar water heating systems:** Passive solar water heating systems – Thermal siphon systems, Integrated collector storage systems; Active solar water heating systems – Direct circulation systems, Indirect water heating systems, Air water heating systems, Heat pump systems, and pool heating systems; Heat storage systems – air system and liquid system thermal storage, and Thermal analysis of storage systems; Module and array design; Solar water heater performance evaluation.

**Solar space heating and cooling:** Thermal load estimation; Heat extraction rate and room temperature; Passive space heating design; Service hot water and space heating; Air systems and water systems for solar space heating and cooling; Industrial process heat generation – air and water systems; Solar steam generation systems; Heat pump systems; Solar buildings; Green houses; Solar cooling by adsorption systems, absorption systems and by absorption refrigeration systems.

**Solar cookers and solar driers:** Types of solar cookers; Solar box type solar cooker; SK type solar cooker (parabolic); Solar steam cooking system; Solar bowl cooking concentrators; Classification of solar driers; Active and passive solar energy driers; Roof integrated solar heating systems.

**Solar desalination:** Thermal desalinization process and exergy analysis; Direct collection systems - solar stills and types, basin type solar stills, performance of solar stills; indirect collection systems – multistage flash process, multiple effect boiling process (humidification –dehumidification distillation); Vapour compression, reverse osmosis and electro-dialysis processes.

**Photovoltaic systems:** Semiconductors; Photovoltaic panels; Types of photovoltaic technologies; Equipment related to photovoltaic technology – batteries, invertors, charge controllers, peak power trackers; Design aspects of photovoltaic systems; Concentrating photovoltaic systems; Hybrid photovoltaic/thermal systems.

**Solar thermal power systems:** Solar thermal power generation schemes; Parabolic trough solar power generating systems; Central receiver power plants (solar power towers); Solar chimney power plants; Dish sterling systems; Solar ponds, design aspects of solar thermal devices, Thermal analysis of solar power plants.

**Design and modelling of solar energy systems:** F-chart method and program; Modelling and simulation of solar energy systems; Artificial intelligence in solar energy systems; Performance and design of liquid based solar heating systems, air based solar heating systems, and of solar service water systems.

**Laboratory Work:** Performance characteristics of solar flat plate collector, parabolic collector, solar stand PV system, solar water heating system, field visit of solar park etc.

**Course Outcomes:**

- Gaining appropriate knowledge on solar energy based thermal power plant
- Gaining awareness on working, construction and performance evaluation of solar photovoltaic and solar thermal devices
- Describe the challenges and problems associated with the use of solar energy and its impacts on environment

**Recommended Books:**

1. *Kalogirou S, Solar Energy Engineering : Processes and Systems, Academic Press, USA( 2009).*
2. *Sukhatme SP, Solar Energy: principles of Thermal Collection and Storage, Tata McGraw-Hill (1996).*
3. *Tiwari GN, Solar Energy-Fundamentals, Design, Modelling & Applications , Narosa (2009)*
4. *Garg HP and Prakash J, Solar Energy fundamentals & Applications , Tata Mc-Graw Hill (2000)*

## PEN207 ENERGY MANAGEMENT SYSTEMS AND AUDITING

L	T	P	Cr
3	1	0	3.5

### Course Objectives:

- To provide understand on the structure and functioning of energy management systems.
- To train students on the auditing of management systems in general and energy management systems in particular.
- To train students on energy analysis of organizations and on the development of energy baseline for organizations.

**Introduction:** Energy resources; Environment, climate change and sustainability.

**Energy management:** Energy supply management and energy demand management; Energy resources allocation and efficient energy use for energy conservation; Legal and other requirements applicable to energy management; Energy and environmental impacts including green house gas emissions.

**Energy monitoring, measurement and analysis:** Energy performance indicators; Energy monitoring devices and instruments; Energy monitoring, measurement and analysis.

**Energy analysis:** Energy review; Development of energy baseline and energy plans.

**Energy management systems:** Management systems approach for energy management in organizations; Energy management systems and requirements of ISO 50001; Development, implementation, maintenance and improvement of energy management systems.

**Auditing and certification of energy management systems:** ISO 19011 and internal and second party auditing of energy management systems; ISO 17021 and third party auditing and management system certification/registration.

**Case study:** Energy management system auditing case study.

### Course Outcomes:

- Able to carry out development, implementation and maintenance of ISO 50001 based Energy Management System.
- Able to utilize the techniques and skills of Energy Management System Auditing.
- Able to utilize the techniques and skills of energy analysis of organizations and development of energy baseline of organizations.

### Recommended Books

1. *ISO 19011: 2011- Guidelines for auditing management systems.*
2. *ISO 17021: 2011 - Conformity assessment — Requirements for bodies providing audit and certification of management systems.*
3. *ISO 50001: 2011 - Energy management systems — Requirements with guidance for use.*
4. *Thumann and W.J. Younger: Handbook of energy audits, Fairmont Press, Georgia, USA (2003).*
5. *Bureau of energy efficiency, New Delhi, India: Guide Book - National certificate examination for energy management and energy audit, 2<sup>nd</sup> ed.2005 (Book I - General aspect of energy management and energy audit; Book II - Energy efficiency in thermal utilities; Book III - Energy efficiency in electrical utilities; and Book IV - Energy performance assessment for equipment & utility systems).*

## PEN208 ELECTRICAL ENERGY AND MANAGEMENT

L	T	P	Cr
3	1	0	3.5

### Course Objectives:

- To provide basic understanding of typical electrical energy powered utilities and services of industrial facilities and organizations.
- To make the student aware of the tools and techniques, and the management practices for the conservation and management of electrical energy.
- To train the student on the electrical energy analysis of organizations for identifying the opportunities and options for the conservation and management of electrical energy.

**Electrical energy:** Electrical energy source and supply scenario; Electrical energy and GHG emissions; Supply side management of electrical energy; Regulatory provisions relating to electrical energy supply and management; Electricity pricing, and rebate and penalty schemes applicable to electrical energy.

**Electrical power systems of organizations:** Electrical power system and its components; Rectifiers and transformers, and energy losses; Power regulation panels and distribution systems and losses; Capacitors and power factor regulation; Electrical load management and demand control; Environmental concerns of electrical power systems.

**Electrical furnaces and heaters:** Types and classification of furnaces; performance evaluation of a furnace; furnace efficiency testing; fuel economy measures for furnaces.

**Motors and drives:** Losses in induction motors, Motor efficiency, Factors affecting motor performance, Rewinding and motor replacement issues, energy efficient motors, variable speed and variable frequency drives.

**Pumps, fans and blowers:** Saving potential, Fans, Blowers and pumps- Types, Performance evaluation, Efficient system operation, Flow control strategies and energy conservation opportunities.

**Lighting, heating/cooling and ventilation systems:** Air Handling Units; Luminance requirements and choice of lighting; Electrical energy conservation avenues; natural lighting and passive systems for ventilation.

**Compressed air system:** Compressed air systems and their energy and environmental analysis; Types of air compressors and efficiencies, and efficient operation of compressors; Capacity assessment, Leakage test Factors affecting the performance and efficiency.

**HVAC and refrigeration System:** Vapor compression refrigeration cycle, Refrigerants, Coefficient of performance, Factors affecting refrigeration and air conditioning system performance and savings opportunities, Vapor absorption refrigeration system: Working principle, Types and comparison with vapor compression system.

**Case study:** Electrical energy auditing and management case study.

### Course Outcomes:

- Becoming aware of typical electrical energy powered machinery and equipment of organizations, specially the industrial units.
- Having the knowledge and awareness of the tools and techniques and the management practices for the conservation and management of electrical energy in organizations.
- Acquiring the techniques and skills of electrical energy analysis and identification of opportunities and options for electrical energy conservation and management.

### Recommended Books:

1. *Abbi Y P and Jain S , Handbook on Energy Audit and Environment Management, Teri Bookstore (2006).*
2. *Diwan P, Energy Conservation, Pentagon Press (2008).*
3. *Doty S, and Wayne C. Turner, Energy Management Handbook; The Fairmont Press, Inc. ( 2009).*
4. *Younger, W., Handbook of Energy Audits, CRC Press (2008).*
5. *Bureau of Energy Efficiency, New Delhi, India: Guide Book (Book III –IV) - National certificate examination for energy management and energy audit( 2005) 2<sup>nd</sup> ed.*

## PEN209 THERMAL ENERGY AND MANAGEMENT

L	T	P	Cr
3	1	0	3.5

### Course objectives:

- To provide basic understanding on combustion of fuels, generation of thermal energy, and on the typical thermal energy utilities and services of organizations.
- To understand the structure and functioning of thermal energy systems - boilers and steam system, thermic fluid systems and cooling water systems.
- To train the student on the thermal energy analysis of organizations for identifying the opportunities and options for the thermal energy conservation and management.

**Boilers:** Fuels and their properties; Combustion of fuels and combustion calculations; Boiler types and classification; Steam boilers, hot water boilers and thermic fluid boilers; Boiler system and components (ID and FD fans, furnace, boiler, economizer, air preheater, heat recovery unit, air pollution control devices and stacks); Boiler feed water and boiler water treatment; Boilers operation and control and boiler blowdowns; direct and indirect boiler efficiency estimation; and energy conservation opportunities in boilers.

**Cogeneration:** Principle and need of cogeneration; Classification of cogeneration systems; technical options for cogeneration; Steam turbines and gas turbines; and Parameters of cogeneration performance.

**Steam and condensate system:** Properties of steam; Steam supply and condensate recovery systems and their components; Steam and condensate system design; Pressure reducing systems; Steam traps and vents; and Energy losses in steam and condensate system and energy saving opportunities.

**Furnaces:** Types and classification of furnaces; Furnace system and components; Energy performance evaluation of furnaces; Pollution control devices and energy recovery systems for furnaces; and Fuel economy measures for furnaces.

**Insulation and refractories:** Purpose, types and applications of insulation; Heat loss calculations and design of insulation thickness; Properties, types and applications of refractories; Heat loss calculations, and selection and design of refractories.

**Heat exchangers:** Heat exchangers and their types; Heat exchanger analysis methods; Performance assessment of heat exchanges; and Fouling of heat exchange surfaces and maintenance of heat exchangers.

**Cooling towers and circulating cooling water systems:** Circulating cooling water system and components; performance evaluation of cooling tower and circulating cooling water system; Conditioning of cooling water and management of cooling tower blowdowns.

**Case study:** Thermal energy auditing and management case study.

### Course Outcomes:

- Having basic understanding of combustion process and knowledge of on-site thermal energy generation systems, insulation and typical thermal utilities and services of organizations.
- Becoming aware of the structure and functioning of thermal energy systems of industrial units and organizations.
- Student acquired the techniques and skills of thermal energy analysis and identification of opportunities and options for the thermal energy conservation and management.

### Recommended books:

1. Thumann A and Younger WJ, *Handbook of Energy Audits*, Fairmont Press, Georgia, USA (2003).
2. Bureau of Energy Efficiency, New Delhi, India: *Guide Book (Book II) - National certificate examination for energy management and energy audit (2005) 2<sup>nd</sup> ed.*
3. Doty S, and Wayne C. Turner, *Energy Management Handbook; The Fairmont Press, Inc. (2009).*