SAVITRIBAI PHULE PUNE UNIVERSITY
(Formerly University of Pune)

Revised Syllabus for M. Tech (Energy Technology)
from Academic Year 2022-23 onwards

FACULTY: FACULTY OF SCIENCE AND TECHNOLOGY
BOARD: Energy TECHNOLOGY

Centre for Energy Studies
Savitribai Phule Pune University
Pune 411 007

July 2022

Savitribai Phule Pune University,
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Revised Syllabus for M. Tech (Energy Technology)

The course consists of four semesters, each semester having five courses. The semester wise courses are given below.

Semester – I		Credits
EN-111	Energy Policy and Energy Economics	**3**
EN-112	Fundamentals of Electrical Energy Systems	**3**
EN-113	Fundamentals of Mechanical Energy Systems	**3**
EN-114	Fundamentals of Thermal Energy Systems	**3**
EN-121	Energy Laboratory – I	**4**
	Elective Courses (Any One)	
EN-131	Environmental Impact of Energy Systems	**4**
EN-132	Energy Management	**4**
		4
Semester – II		
EN-211	Plant Instrumentation & Control	**4**
EN-212	Renewable Energy Technologies	**4**
EN-213	Energy Audit and Management – I	**4**
EN-221	Energy Laboratory – II	**4**
	Elective Courses (Any One)	
EN-231	Data Analytics	**4**
EN-232	Advanced Solar Photovoltaic Systems	**4**
EN-233	Advanced Solar Thermal Systems	**4**
Semester – III		
EN-311	Energy Audit and Management – II	**4**
EN-312	Assessment of Thermal Energy Systems	**4**
EN-313	Steam Utilization	**4**
EN-321	Industrial/ Laboratory training (Mini Project)	**4**
Elective Courses (Any One)		
EN-331	Wind Energy Systems	**4**
EN-332	Waste to Energy	**4**
EN-333	Energy Storage	**4**
Semester – IV		
EN-421	Industrial project/Research project (Major Project)	**16**
	Elective Courses (Any One)	
EN-431	Research Paper	**04**

Learning Outcome – M. Tech. (Energy Technology) Program: The energy security is of prime importance for every nation. In last decade, in our country several steps have been taken to ensure the energy security. Typically, there is a quantitative shift from fossil fuels to renewable sources. Keeping this in mind, courses are designed for the MTech. program. Course on energy related policies updates student with respect to the rules and regulations to be followed in practice. The student is made verse with the energy auditing which is most essential part of knowing the status and consumption pattern of energy. There are courses that provide information on the wind, Photo Voltaic, Photo Thermal and hydro energy. Special course on boilers make the student aware of use of boilers and its importance in today's industry. Energy storage, its means and limitations are taught. Students get hands on design experience for limited Photo voltaic and Photo Thermal systems. The experimental courses provide hands on training in energy audit, HVAC systems, trouble shooting in PV systems. Thus, a student is prepared with basic understanding of various renewable resources and skills to work in the real application in the society.

Semester-I

Distribution of Credits and Modules

Course Code	Course Title and Modules	Credits
EN-111	**Energy Policies and Energy Economics**	**3**
	Module 01: Energy Laws and Energy Policies in India	1.0
	Module 02: Demand for and Supply of Energy	0.5
	Module 03: Concept of Markets with Special Reference to Energy Markets	0.5
	Module 04: Demand for and Supply of Energy	0.5
	Module 05: Link Between Sustainable Development, Economics of Climate Change, and Energy Policy	0.5
EN-112	**Fundamentals of Electrical Energy Systems**	**3**
	Module No.1: Basics of Electrical Energy Systems	1
	Module No.2: Motors, Transformers and Switch Gears	2
EN-113	**Fundamentals of Mechanical Energy Systems**	**3**
	Module No.1: Basics of Mechanical Energy Systems and Utility Systems	1.5
	Module No 2: Refrigeration Systems and Air Conditioning System	1.5
EN-114	**Fundamentals Thermal Energy Systems**	**3**
	Module No.1: Basics of Thermodynamics	0.5
	Module No.2: Combustion and Heat transfer	1
	Module No.3: Heat generating equipment's	1
	Module No 4: Industrial Furnaces	0.5
EN-121	**Energy Laboratory- I**	**4**
	Elective Courses	
EN-131	**Environmental Impact of Energy Systems**	**4**
	Module No.1: Impact of Energy systems on Environment	1
	Module No.2: Pollution due to Thermal, Hydel and Nuclear Power Plants	1
	Module No.3: Pollution due to Vehicles and Utilities	1
	Module No 4: Environmental and Pollution Control Laws	1
EN-132	**Energy Management**	**4**
	Module 1: Basic electricity framework in India	1
	Module 2: National level Energy Policies / Missions	1
	Module 3: Electricity Pricing framework in India	1
	Module 4: System operation and Electricity Market operation	1

DETAIL SYLLABUS FOR SEMESTER-I

EN 111: ENERGY PLICIES AND ENERGY ECONOMICS (3 Credits)
[Note: Before teaching this syllabus, the teacher should deal with some basic concepts in Economics such as Public Goods, Production Possibility Frontier, Economies of scale, Externalities, Market failures etc. and teach with the Case studies wherever applicable]

Module 01: Energy Laws and Energy Policies in India (C-1, L- 10, 5 -S/ D/ T)
Energy Conservation Act of 2001, The Electricity Act, 2003, Electric Vehicle Policies of Government of India & various state governments, Policies of Government of India for Solar Energy, the amendments in these acts.

Module 02: Energy Economics: Background (C- 0.5, L- 5, 3-S/ D/ T)
Origin and Definitions of Energy Economics, Link between Economics and Energy, Energy Resources and Energy Commodities; Properties of Energy Resources and Energy Commodities, concept of Energy conservation and Energy efficiency

Module 03: Concept of Markets with Special Reference to Energy Markets (C-1, L- 10, 5 -S/ D/ T)
Global and National scenario, Trend and Patterns of Energy Consumption and the Energy Crisis (since 1970 the Oil shocks and other events)
Energy Pricing and Taxation: Production Cost versus Return on Investment, Models of Pricing, Market Failures, Peak and Off-peak Pricing, Subsidies
Energy Finance: Banks, International organizations, Green Finance initiatives

Module 04: Demand for and Supply of Energy (C-1, L- 10, 5 -S/ D/ T)
Demand for Energy as a Derived Demand, World Energy Consumption – Economic Growth and World Energy Consumption, Demand substitution and energy use
Classification of Energy supplies: renewable and non-renewable, Fossil fuels (coal, oil, natural gas), Renewable energy (Hydro, Marine, wind, solar, Geothermal, bio), Nuclear power, Trend and patterns of energy production

Module 05: Link Between Sustainable Development, Economics of Climate Change, and Energy Policy (C-1, L- 10, 5 -S/ D/ T)
Concept of Sustainable Development and SDGs, Energy Security: India's initiatives, Energy and Climate Change, Energy Efficiency and carbon emissions: Global and National trends, Energy Policy

The Economics of Climate Change, Climate Change Background, Overview of GHG Emissions, Economic Approach to Control the Greenhouse Effect,
Options to Cope with Global Warming, Generic Options, National Policy Options, Emissions Trading System (ETS)

Grading and assessment would include a Research Project / Term Paper/ Field visit to Energy company/firm and report writing

Learning Outcomes:
After completing this course, student should be able to:
1) Learn the basics of Laws and Policies related to energy sector in India.
2) Learn terms in economics related to energy.
3) Learn the concepts of Energy Pricing and Taxation
4) Demand for Energy as a Derived Demand and energy as growth engine.
5) Policies related to economics, climate change and environmental impact.

Reference readings:

[1] Pindyck, R., and D. Rubinfeld. Microeconomics. 6th ed. Upper Saddle River, NJ: Prentice Hall, 2005. ISBN: 0130084611
[2] International Energy Markets: Understanding Pricing, Policies, and Profits. 2nd Edition. Carol A. Dahl. PennWell.
[3] Energy Economics: Concepts, Issues, Markets and Governance by Subhes C. Bhattacharyya Springer Science & Business Media, 28-Feb-2011
[4] Energy Economics: Theory and Applications Peter Zweifel, Aaron Praktiknjo, Georg Erdmann Springer, 27-Mar-2017
[5] Energy for a sustainable world: Jose Goldenberg, Thomas Johansson, A.K.N.Reddy, Robert Williams (Wiley Eastern).
[6] Energy policy: B.V. Desai (Weiley Eastern).

[7] Modeling approach to long term demand and energy implication: J. K. Parikh.
[8] Energy Policy and Planning:B.Bukhootsow.
[9] TEDDY Year Book Published by Tata Energy Research Institute (TERI).
[10] World Energy Resources: Charles E. Brown, Springer 2002.
[11] International Energy Outlook-EIA annual Publication.
[12] Heat and Thermodynamics – M.W. Zemansky (McGraw Hill Publication).
[13] Principles of Energy Conversion: A.W. Culp (McGraw Hill International edition).
[14] BEE Reference book: no.1/2/3/4.

EN 112: FUNDAMENTALS OF ELECTRICAL ENERGY SYSTEMS (3 Credits)

Module 01: Basics of Electrical Energy System (C-1, L- 10, 5 -S/ D/ T)

Essence of electricity, Conductors, semiconductors and insulators (elementary treatment only); Electric field; electric current, potential and potential difference, electromotive force, electric power, ohm's law, basic circuit components, electromagnetism related laws, Magnetic field due to electric current flow, force on a current carrying conductor placed in a magnetic field, Faradays laws of electromagnetic induction. Types of induced EMF's, Kirchhoff's laws

Magnetic field due to electric current flow,force on a current carrying conductor placed in a magnetic field, Faradays laws of electromagnetic induction. Types of induced EMF's, Kirchhoff's laws, Network Analysis : Basic definitions, types of elements , types of sources, resistive networks, inductive networks, capacitive networks, series parallel circuits, star delta and delta star transformation ,Alternating Quantities : Principle of ac voltages , waveforms and basic definitions, relationship between frequency, speed and number of poles, root mean square and average values of alternating currents and voltage, form factor and peak factor, phasor representation of alternating quantities.

Module 02: Motors, Transformers and Switch Gears (C-2, L- 20,5 -S/ D/ T)

AC Induction: Three phase induction motor, principle of operation, slip and rotor frequency, torque. AC Synchronous: Principle of operation, EMF equation. HT Motors: Difference between HT and LT motors, Advantages, Construction. DC: Direct current machines: Principle of operation of dc machines, armature windings, e.m.f equation in a dc machine, Torque production in a dc machine, Operation of a dc machine as a generator, operation of a dc machine as a motor Starters and Protection. Types of motor controllers, Motor starters DOL, Reduce voltage starters, ASD, Overload relays, Servo controllers etc Starting and Load Characteristics Motor torque speed characteristics, Opportunities for efficiency improvement.

Power Transformers: Principles of operation, Constructional Details, Losses, Transformer Test, Efficiency and Regulation, New type of transformers like hermetically sealed and amorphous

Distribution Transformers: Definition, types and Classification, Connections, Load, No load losses, efficiency, Protection and Switchgear: Power conducting components, such as switches, circuit breakers, fuses, and lightning arrestors, that conduct or interrupt the flow of electrical power - Control systems such as control panels, current transformers, potential transformers, protective relays, and associated circuitry, that monitor, control, and protect the power conducting components. Opportunities for efficiency improvement

Selection and sizing of AC Synchronous, AC Induction, DC motors, Variable Speed Drives: AC Drives-Applications, Principle, Controller types of inverter, DC Drives: 4-Quadrant Drives, Cabling and Distribution: Cable Sizing ,Power Factor Correction, Harmonics: Manifestation, Causes Norms, Control and Correction, Lighting systems, Opportunities for efficiency improvement.

Learning Outcomes:

After completing this course, student should be able to:

1) Fundamental of electrical energy systems and its components. Conversion of electric and magnetic fields.
2) Kirchhoff's law and its relevance to electrical energy.
3) Electrical network analysis and star-delta and delta star transformation.
4) Power factor and phasor representation of alternating quantities.
5) Fundamentals of motors and switchgears
6) Selection and sizing of AC synchronous, AC induction, and DC motors.

REFERENCE BOOKS:

[1] Principles of Energy Conversion: A.W. Culp.
[2] Direct Energy Conversion: M.A. Kettani
[3] Energy Conversion systems: Begamudre, Rakoshdas
[4] Direct Energy Conversion: W.R.Corliss.

[5] Alternative Liquid fuels: B.V. Desai.
[6] TEDDY year book published by TERI.
[7] The Watt Committee on Energy (Reports).
[8] Energy Management Workbook
[9] NIFES Report -Computers in Energy Audits.
[10] Efficient Use of Energy: I. E. C. Dryden (Butterworths)
[11] Instrument Engineers handbook (VolI,II,III), B.G. LiptakChintan Book Comp /CRC Publication
[12] Analysis and design of Energy Systems- B. K. Hogde (Prentice hall 1988)

EN 113: FUNDAMENTALS OF MECHANICAL ENERGY SYSTEMS (3 Credits)

Module 01: Basics of Mechanical Energy Systems and Utility Systems (C-1.5, L- 15,5 -S/ D/ T)

Modules of mechanical engineering, Mechanical Engineering and Overview: Basic Engineering concepts and design considerations, Governing regulations and codes and standards, Strength of Materials, mechanical properties of materials, mechanics of materials, Torque and Power: Basic theory, Shafts, Flywheels etc., Power Transmission: Concepts of Belts Drives, Gearing, Coupling etc. Bearing and Lubricants as Energy Saving Measures. Electromechanical energy: Electric to mechanical energy conversion, Electric Motors.

Compressors, Fans, Pumps Compressed Air System: Types of air compressors, compressors efficiency, efficient compressors operation, Compressed air system components, capacity assessment, and leakage test, factors affecting the performance. Fans and blowers: Types, performance evaluation, efficient system operation, flow control strategies. Pumps and Pumping Systems: Types, performance evaluation, efficient system operation, flow control strategies, variable speed drives. Cooling Towers: Types and performance evaluation, efficient system operations, flow control strategies, assessment of saving opportModuleies.

Module 02: Refrigeration Systems, air conditioning systems (C-1.5, L- 15, 5 -S/ D/ T)

Air Conditioning: Vapor compressor refrigeration cycle, refrigerants, coefficient of performance, capacity, factors affecting refrigeration and air conditioning system performance, Vapor absorption refrigeration systems: Working principle, type and comparison with vapor compressor system. Thermal storage in refrigeration.

Learning Outcomes:

After completing this course, student should be able to:

1) Learn the fundamentals of the Mechanical Energy Conversion applications and devices used therein.
2) Develop ability to observe, understand, reason, generalize, forecast, and ask questions in mechanical energy systems.
3) Utilize the abstractions of mathematics to resolve physical issues.
4) Arouse interest in innovative research, technology, and the sciences, provide fresh concepts and investigate issues, capable of working both individually and together

REFERENCE BOOKS:

[1] Energy management and control system-Vol-I, II –M.C.Macedo (John Willy)
[2] Energy Conservation guide book Patrick/Patrick/Fardo (Prentice hall1993)
[3] Handbook on Energy efficiency.
[4] ASHRAEE Energy Use (4 Volumes),
[5] CIBSI –guide –User's Manual (U.K.)
[6] Aspects of Energy Conversion: I.M.Blair and B.O.Jones
[7] Principles of Energy Conversion: A.W.Culp (McGrawHill International
[8] Energy conversion principles: Begamudre Direct Energy Conversion: W.R.Corliss and Rakoshdas
[9] Principles of Refrigeration R.J. Dossat (Wiley Estern Limited.)
[10] Efficient Use of Energy: I.E.C.Dryden (Butterworths)
[11] Instrument Engineers handbook (VolI,II,III)– B.G. LiptakChintan Book Comp /CRC Publiation
[12] Analysis and design of Energy Systems - Hogdeb.K. (Prentice hall 1988)

EN114: FUNDAMENTALS OF THERMAL ENERGYSYSTEMS (3 Credits)

Module 01: Basics of Thermodynamics (C-0.5, L- 05, 5 -S/ D/ T)

Basic Modules, Dimensions and Conversions For Energy, Concepts of Energy, Heat and Work, Ideal Gas law, 1stand 2ndlaw of Thermodynamics (Closed and Open Systems), Thermodynamics Power Cycles, Reversible Heat Engine Cycle, IC Engine Cycles, Carnot Cycle, Rankine Cycle, Otto Cycle, Vapor Refrigeration and Power Cycle etc.

Module 02: Combustion and Heat transfer (C-1, L- 10,5 -S/ D/ T)

Stoichiometry, HeatTransfer, Fuels and Fuel Treatments

Module 03: Heat generating equipment's (C-1, L- 10,5 -S/ D/ T)

Boilers: Combustion and Flue Gas Handling, Thermic Fluid Systems, Hot Air/ Water Generators

Module 04: Industrial Furnaces (C-0.5, L- 05,5 -S/ D/ T)

Furnaces, Incinerators, Dryers

Learning Outcomes:

After completing this course, student should be able to:

1) students should be able to use fundamental principles of fluid mechanics to solve thermal problem.
2) use basic principles of thermodynamics to solve thermal problem.
3) use basic principles of heat transfer and mass transfer to solve thermal problem.
4) gain knowledge of advanced features of fluid mechanics, thermodynamics, heat and momentum transfer pertaining to thermo-fluid problem,
5) understand the significance of course content for thermo-fluid problems, apply knowledge in analysis and interpretation of thermo-fluid problem, Analyze and evaluate an existing thermal system and recommend their idea.

REFERENCE BOOKS:

[1] Direct Energy Conversion: W.R.Corliss
[2] Aspects of Energy Conversion: I.M.Blair and B.O.Jones
[3] Principles of Energy Conversion: A.W.Culp (McGrawHill International
[4] Energy conversion principles: Begamudre , Rakoshdas
[5] Fuel Economy Handbook, NIFES
[6] Industrial Furnaces (Vol I & II) and M.H. Mawhinney (John Wiley Publications)
[7] Refractories-F.H. Nortan(John Wiley Publication.)
[8] Refractories and their Uses-Kenneth Shaw, (Applied Science Publishers Ltd.)
[9] Refractory Material G.B. Rotherberg (Noyes data Coorp. N.I)
[10] The storage and handling of Petroleum liquid (John R. Hughes, Charles Griffin & Co. Ltd.)
[11] Fuels and fuel Technology Wilfred Francis, (Pergamon press)
[12] Domestic and commercial oil Burners Charles H. Burkhadt (McGraw Hill Publication)
[13] The efficient use of steam – Oliver Lyle, (HMSO London)
[14] Boilers-Types, Characteristics and functions-Carl D. Shields (Mcgraw Hill book)
[15] The Efficient use of steam generation-General editor-P.M.Goodall
[16] Principles of Refrigeration R.J. Dossat (Wiley Eastern Limited.)
[17] Stoichiometry-Bhatt, Vora (Tata Mc.Graw Hill)
[18] Practical Heat Recovery-Boyen J.L. (John Wiley, New York, USA1976)

EN 121: Energy Laboratory-I (4 credits) (Any 10 Experiments)

1. Determination of efficiency of boiler and analysis of flue gases.
2. Study of heat exchangers.
3. Study of variable speed drives
4. COP of cooling towers.
5. Efficiency of electrical motors.
6. Study of diesel generator set.
7. Measurement of load and power factor for the electrical utilities.
8. Determination of efficiency of pumping system.
9. Performance evaluation of blower
10. Performance evaluation of air compressors
11. Determining efficiency of lighting system/loads
12. Introduction to Energy measuring instrument

Learning Outcomes:

After completing this course, student should be able to:

1) supplement various topics related to energy aspects in class-room lectures to experimental setups and working.
2) The experiments based on science / engineering principles are designed to provide students enough stimulation for further investigation.
3) provide ground for the analytical subject material in a practical problem, meaning that the skills and knowledge students learn throughout the program will be applied in real renewable energy engineering work.

EN 131: ENVIRONMENTAL IMPACT OF ENERGY SYSTEMS (4 Credits)

Module01: Impact of Energy Systems on Environment (C-1, L- 10,5 -S/ D/ T)

Environmental degradation due to energy production and utilization, Primary and Secondary pollution due to Green House Gases Emission such as SOx, NOx, SPM in air, thermal and water pollution, depletion of ozone layer, global warming, Positive and Negative Impacts, biological damage due to environmental degradation, Sociological and Economical problems due to thermal and other energy projects, Physiological, ecological, environmental and health problems due to energy plants, Industrial and urban waste, Pollution control: Causes, Process and exhaust gases and its control, mechanism and devices for pollution control. Methods of Environmental Impact Assessment (EIA), Principles, origin and development of EIA, Essential components of EIA, Project Screening, Baseline study, Impact Identification, Impact prediction, evaluation and mitigation, methodology matrix method, network, overlay, problems of EIA in developing countries, Future of EIA.

Module02: Pollution due to Thermal, Hydel and Nuclear Power Plants (C-1, L- 10,5 -S/ D/ T)

Potential sources of pollution in thermal power plant, air, water, land pollution due to emission for thermal power plant. Environmental pollution limits guidelines for thermal power plant pollution control. Various pollution control equipment's such as dust collector, bag filter, electrostatic separator, working principle and selection criteria, designing the pollution control system, methods and limitation. Water pollution in thermal power plant, physical and chemical methods of pollution control, Land pollution, effect of land pollution, measurement of land pollution. Limitations and advantages of pollution control systems. Hydrothermal plant environmental assessment, hydrothermal plant and rehabilitation measures for hydrothermal plant. Nuclear power plants and environmental pollution, pollution control measures.

Module03: Pollution due to Vehicles and Utilities (C-1, L- 10,5 -S/ D/ T)

Pollution due to vehicles and utilities, methods to control emission from vehicle, boilers, furnaces etc, International Standards for quality of air and norms for exhaust gases. Effect of hydroelectric power stations on ecology and environment.

Module04: Environmental and Pollution Control Laws (C-1, L- 10, 5 -S/ D/ T)

Moduleed Nations Framework Convention on Climate Change (UNFCC), Protocol, Conference of Parties (COP) 19 Clean Development Mechanism (CDM), Prototype Carbon Funds (PCF) Carbon Credits and it's trading, Benefits to developing countries, Building a CDM project.

Learning Outcomes:

After completing this course, student should be able to:

1) learn interactions between the environment and energy conversion systems, with particular reference to pollution processes (both chemical and thermal) and to the impacts related to power plants.

2) Students will be provided with fundamentals required for the understanding of most important solutions and techniques to limit the effects of the use of power plants, with reference to the actual knowledge and to engineer responsibilities in this field.

REFERENCE BOOKS:

[1] Management of Energy Environment Systems -W.K.Foell (John Wiley and Sons).
[2] Energy Management and Control Systems -M.C.Macedo Jr. (John Wiley and Sons).
[3] Environmental Impact Analysis Handbook -J.G.Rau, D.C.Wood (McGraw Hill).
[4] Energy and Environment – J.M. Fowler, (McGrawHill)
[5] Environmental Impact Assessment, Clark D. Brain, Biesel Donald
[6] EIA for Developing Countries, Biswas Asit. K.
[7] EIA Guidelines 1994, Notification of Govt. of India Impact Assessment
[8] Methodologies & Procedures.
[9] Environmental Impact Assessment W. Canter (IInd Edition)
[10] Auditing for Environmental Quality Leadership Willing, T-Johan
[11] Environmental Audit Mhastear A. K.
[12] Hugh Barton and NeolBrudes, A Guide to local Environmental Auditing, EarthscanPublications Ltd. (1995)

EN - 132: ENERGY MANAGEMENT (4.0 CREDITS)

Module 1: Basic electricity framework in India (C-1, L- 05, 5 -S/ D/ T)

Generation, Transmission, Distribution, National grid, interstate and intra-state transmission network, key stakeholders at national and state level, role and responsibilities of key stakeholders.

Module 2: National level Energy Policies / Missions (C-1, L- 05, 5 -S/ D/ T)

National Energy Plan, National Electricity Policy, Tariff Policy, Energy storage policy, Key provisions of Electricity Act 2003 and Regulations, Provisions related to energy management like role and responsibilities of key stakeholders, electricity grid code,

Module 3: Electricity Pricing framework in India (C-1, L- 05, 5 -S/ D/ T)

Various provisions of Electricity Act 2003 which governs the electricity pricing, various methodologies for computation of electricity price for conventional generation and renewable energy technologies.

Module 4: System operation and Electricity Market operation (C-1, L- 05, 5 -S/ D/ T)

system operation in India at national /regional/state level, real time load-generation balance, electricity scheduling and dispatch process, real time deviation management regulations, Reserve requirement, types of reserves, Ancillary services framework, Security constraint Economic Despatch (SCED) and Security Constraint Unit Commitment (SCUC), Electricity Market in India, Electricity Exchanges, types of electricity markets, Day ahead market (DAM), Real Time Market (RTM), Capacity Market, Market Clearing Price, Area clearing price

Learning Outcomes:

After completing this course, student should be able to:

1) create framework for thorough energy audits.

2) learn to analyse the use of sustainable energy management techniques, examine greener management techniques, technology, and energy sources.

3) get skills to implement energy conservation initiatives.

4) allow students to use adaptive technologies and management techniques to integrate the energy sources to the fullest.

Reference Books:

[1] Energy policy: B.V. Desai (Weiley Eastern).

[2] Modeling approach to long term demand and energy implication: J. K. Parikh.

[3] Energy Policy and Planning: B.Bukhootsow.

[4] International Energy Outlook-EIA annual Publication.

[5] Heat and Thermodynamics – M.W. Zemansky (McGraw Hill Publication).

[6] BEE Reference book: no.1/2/3/4.

[7] Energy Management, Audit and Conservation" by Barun Kumar De

[8] Guide to Energy Management" by Barney L

Semester-II

Distribution of Credits and Modules

Course Code	Course Title and Modules	Credits
EN-211	**Plant Instrumentation and Control**	**4**
	Module 01: Basic Instrumentation System	1
	Module 02: Basic Signal Conditioning Elements, Deflection Measurement	1
	Module 03: Industrial Measurements	1
	Module 04: Control Systems, Data Storage and Transmission	1
EN-212	**Renewable Energy Technologies – I**	**4**
	Module 01: Solar Thermal and Solar Photovoltaic Energy	1
	Module 02: Wind Energy	1
	Module 03: Geothermal, Tidal and Wave Energy	1
	Module 04: Industrial and Urban Waste and Waste Energy Recovery	1
EN-213	**Energy Audit and Energy Management – I**	**4**
	Module 01: Instruments used for Energy Audit Measurements	1
	Module 02: Measurement Methods for each in Audit Instrument section	1
	Module 03: Auditing of Energy Generating and Energy using systems and Equipment	1
	Module 04: Testing and Calculation	1
EN-225	**Energy Laboratory – II**	**4**
	Elective Courses	
EN-231	**Data Analytics**	**4**
	Module-01: Basic data & variables	1
	Module 02: Analysis of data	1
	Module 03: Analysis tools and programming	2
EN-232	**Advanced Solar Photovoltaic Systems**	**4**
	Module No.1: Solar Radiation	1
	Module No.2: Photo Thermal Systems	1
	Module No.3: Photovoltaic Systems	1
	Module No 4: Design, Modeling and Economic Analysis of Solar Energy Systems	1
EN 233	**Advanced Solar Thermal Systems**	**4**
	Module 01: Solar Radiation	1
	Module 02: Solar Thermal Systems	1
	Module 03: Solar Thermals Systems and Components	1
	Module 04: Designing of a Solar Thermal System for industrial process heat application	1

DETAIL SYLLABUS FOR SEMESTER-II

EN 211: PLANT INSTRUMENTATION AND CONTROL (ELECTICE COURSE) (4 Credits)

Module 01: Basic Instrumentation system (C-1, L- 10, 5 -S/ D/ T)

Basic Instrumentation system, Elements of a Measurement System, Errors and Uncertainties, Mechanical Transducers, Temperature- Bimetallic Element and Fluid Expansion Type, Thermometers, Pressure- Manometers, flow measurement of liquids and gases, Bourdon Gauges, Load Cells and Elastic Force Devices, Electrical transducers: Resistive Transducers; Inductive Transducers; Capacitive transducers; Thermoelectric Transducers and Photoelectric Transducers; Piezoelectric Transducers.

Module 02 Basic Signal Conditioning Elements, Deflection measurement (C-1, L- 10, 5 -S/ D/ T)

Basic Signal Conditioning Elements: Balance and Deflection Measurements-Differentiating and Integrating Elements; Filters; Data Transmission Elements- Electrical, Pneumatic, Position and Radio Frequency Transmission types, Basic display elements

Module 03: Industrial Measurements (C-1, L- 10, 5 -S/ D/ T)

Industrial Measurements: Velocity Measurement-Contact type: AC-DC Tachometers Non-contact type: Magnetic, Photoelectric & stroboscopic methods for speed measurement, Measurement of Force: Different methods; Strain gauge load cell method, Radiation Measurement: Radiation Fundamentals; Radiation detectors; Optical pyrometer, lighting measurements, electrical measurements, introduction to thermal imager.

Module 04: Control Systems, Data storage and Transmission (C-1, L- 10, 5 -S/ D/ T)

Control Systems: Open and Closed loop systems, Linear Time-invariant systems, On-Off, Proportional, PI, PD, PID and Feed-forward Control, Control systems: Feedback and non-feedback systems, feedback characteristics of control system. Block diagram, flow graph, regenerative feedback.
Artificial Intelligence, Sensors, Transmitters, Data-loggers, SCADA Systems, DCS Systems, Remote and cloud-based data management, Data Transmission, Serial Communication, LAN, Wireless: GPRS, Wi-Fi, Zigby, Others, Protocols: MODBUS, LONWorks, BACNet,

Learning Outcomes:

After completing this course, student should be able to:

1. Elucidate the construction and working of various industrial parameters / devices used to measure pressure, sound and flow.
2. Explicate the construction and working of various industrial parameters / devices used to measure temperature, level, vibration, viscosity and humidity.
3. Ability to analyse, formulate and select suitable sensor for the given industrial applications
4. Describe signal conditioning circuit.
5. Develop the mathematical model of the physical systems.
6. Analyze the response of the closed and open loop systems.
7. Analyze the stability of the closed and open loop systems.
8. Design the various kinds of compensator.
9. Develop and analyze state space models.

REFERENCE BOOKS:

[1] W. D. Cooper and A.D. Helfrick, Electronic Instrumentation and Measurement Techniques, Prentice Hall of India, New Delhi (1989).
[2] D. Patranabis, Principles of Industrial Instrumentation, Tata McGrew-Hill publishing Company Ltd., New Delhi (1990).
[3] I.J. Nagrath and M. Gopal, Control Systems Engineering, Wiley Eastern Ltd., New Delhi (1990).
[4] S. Malvino, Digital Computer Electronics, Tata McGraw Hill, New Delhi.
[5] Doeblin – Measurement System McGrew Hill Book Co., (1981).
[6] T. R. Padmanabhan, Industrial Instrumentation: Principles and Design, Springer.
[7] J.P. Homan, Experimental Methods for Engineering, 6th edition McGrew Hill Inc.
[8] Instrumentation methods by Chatwal Anand, 3rd edition, Meerut publication house, Meerut
[9] Instrumentation, Measurement and Control – D S Kumar
[10] BC Nakra, and KK Chaudhry; Instrumentation, Measurement and Analysis; 2e, 2004, Tata McGraw
[11] DVS Murthy; Transducers and Instrumentation; 2003, PHI
[12] CS Rangan, GR Sarma, and VSV Mani; Instrumentation Devices and Systems; 2e, Tata McGraw
[13] Doeblin and Ernest; Measurement Systems Application and Design; 5 ed, 2004, Tata McGraw-Hill.
[14] Measurement Systems – Applications & design by Doeblin E.O. 4th ed. Mc. Graw Hill
[15] Principles of Industrial Instrumentation by Patranabis D. TMH – 1997

[16] Mechanical & Industrial Measurements by Jain R.K, Khanna Publishers – 1986
[17] Process Instruments and control Hand book by Considine D.M, 4th ed, Mc.Graw Hill
[18] Instrument Technology – Vol 1 by Jones E.B., Butterworths – 1981
[19] Control Systems Engineering by Nagrath&M.Gopal, Wiley Eastern
[20] Automatic Control Systems by B.C.Kuo, John Wiley, 2009
[21] Modern Control Engineering by Katsuhiko Ogata, Prentice Hall

EN 212: RENEWABLE ENERGY TECHNOLOGIES-I (4 Credits)

Module 01: Solar Thermal and Solar Photovoltaic Energy (C-1, L- 10, 5 -S/ D/ T)

Solar Radiation, availability, measurement and estimation, Solar-Earth geometry,
Solar Thermal: Solar Thermal Conversion Devices and Storage, Applications, Solar thermal energy for industrial process heating, applications of solar flat plate water heater & air heater for industrial process heat, concentrating Solar collector systems, Basic concepts & parameters, Comparison of various designs, industrial applications of concentrating collectors, Exercises in Industrial Applications, Utilization of solar thermal energy.
Solar Photovoltaics: Solar Photovoltaic effect - Principle of direct solar energy conversion into electricity in a solar cell. Solar cell, p-n junction, structure, PV module performance, I-V characteristics of a PV module, maximum power point, cell efficiency, fill factor, effect of irradiation and temperature. Classification of PV systems and components, Distributed PV System, Stand-alone PV system, grid Interactive PV System, small system for consumer applications, hybrid solar PV system, concentrator solar photovoltaic. System components - PV arrays, inverters, batteries, charge controls, net power meters, PV system applications.

Module 02: Wind Energy (C-1, L- 10, 5 -S/ D/ T)

Wind Energy: Basics and Power Analysis, Wind resource assessment, Power Conversion Technologies and applications, Wind Power estimation techniques, Principles of Aerodynamics of wind turbine blade, Various aspects of wind turbine design, Wind Turbine Generators: Induction, Synchronous machine, constant V and F and variable V and F generations, Reactive power compensation. Site Selection, Concept of wind form and project cycle, Cost economics and viability of wind farm.

Module 03: Geothermal, Tide and Wave Energy (C-0.5, L- 05, 5 -S/ D/ T)

Geothermal Energy: Availability of Geothermal Energy-size and Distribution, Recovery of Geothermal Energy, Various Types of Systems to use Geothermal Energy, Direct heat applications, Power Generation using Geothermal Heat, Sustainability of Geothermal Source, Status of Geothermal Technology, Economics of Geothermal Energy.
Tidal Energy: Introduction, Origin and Nature of Tidal Energy, Advantages of Tidal Energy, Limitations of Tidal Energy, Tidal Energy Plant, Energy Potential Estimation, Ocean Tidal Energy Conversion Schemes (Single Basin: Single Effect, Single Basin: Double Effect, Two Basin: Linked Basin, Two Basin: Paired Basin and Tidal Flow or Tidal Current), Global Scenario of Tidal Energy, Tidal Power Development in India
Wave Energy: Introduction, Advantages and Disadvantages of Wave Energy, Power in Waves, Wave Energy Technology (Heaving Float Type Devices, Pitching Type Devices, Heaving and Pitching Float Type Devices, Oscillating Water Column Type Devices and Surge Devices), Global Scenario of Wave Energy, Tidal Power Development in India
Ocean Thermal Energy:Introduction, Origin of Ocean Thermal Energy Conversion and Efficiency, Ocean Thermal Energy Conversion Technology (Open Cycle/Claude Cycle Plant, Closed Cycle/Anderson Cycle Plant, Advantages and Disadvantages of Ocean Thermal Energy Conversion
Global and Indian Status of Ocean Thermal Energy Conversion

Module 04: Industrial and Urban Waste & Waste Energy Recovery (C-0.5, L- 05, 5 -S/ D/ T)

Industrial waste, Waste and effluent treatment, Waste as a source of energy: Industrial, domestic and solid waste as a source of energy.

Learning Outcomes:

After completing this course, student should be able to:
1) Perform an initial design of a renewable energy system.
2) Analyze how changes in functionality in a component will affect the other components of the system.
3) Students will be able to identify, define, present and communicate issues within the subject area.
4) Understand of renewable and non-renewable sources of energy.

5) Gain knowledge about working principle of Geothermal, tide and wave energy.
6) Understand the application of wind energy and wind energy conversion system.
7) Analyze how industrial and urban waste and waste energy recovery is done.

REFERENCE BOOKS:

1. Wind energy Conversion Systems – Freris L.L. (Prentice Hall1990)
2. Wind Turbine Technology: Fundamental concepts of wind turbine technology Spera D.A. (ASME Press, NY, 1994)
3. Wind Energy Systems – G.L. Johnson (Prentice Hall, 1985)
4. Wind Energy Explained – J.F.Manwell, J.G. McGowan and A.L. Rogers (John Wiley & Sons Ltd.)
5. Duffle and Beckman, Solar Thermal Engineering Process, John Wiley & Sons, New York
6. A.B. Meinel and M.B. Meinel, Applied Solar Energy, Addison – Wiley Pub. Co., Reading
7. P.J. Lunde, Solar Thermal Engineering, John Wiley & Sons, New York
8. H.P. Garg, Advanced in Solar Energy Technology, D. Reidel Publishing Co., Drdricht.
9. S.P. Sukhatme, Solar Energy, Tata McGrew Hill Company Ltd., New Delhi
10. M.A. Greaen "Solar Cells – Operating Principles, Technology, and System Applications", 1983 Prentice Hall, Inc. New Jersey.
11. F. Kreith and J.F. Kreider, Principles of Solar Engineering Hemisphere Publishing Coro.
12. Chetan Singh Solanki., Solar Photovoltaic: "Fundamentals,Technologies and application", PHI Learning Pvt., Ltd., 2009.
13. Jha A.R., "Solar Cell Technology and Applications", CRC Press, 2010.
14. John R. Balfour, Michael L. Shaw, SharlaveJarosek., "Introduction to Photovoltaics", Jones & Bartlett Publishers, Burlington, 2011.
15. Luque A. L. and Andreev V.M., "Concentrator Photovoltaic",Springer, 2007.
16. Partain L.D., Fraas L.M., "Solar Cells and Their Applications", 2nd ed., Wiley, 2010.

EN 213: ENERGY AUDIT AND ENERGY MANAGEMENT-I (4 Credits)

Module 01: Instruments used for Energy Audit Measurements (C-1, L- 10, 5 -S/ D/ T)

Ultrasonic water flow meters, Anemometers, Pressure Gauges, Manometers, Thermometers: All types, Power Quality Analyzers and loggers, Infrared Thermometers, Lux meter, Pitot Tubes, Flue gas Analyser: Chemical and Electronic types, Tachometers: Contact and non-contact type, Humidity measurement devices

Module 02: Measurement methods for each in Audit instrument section (C-1, L- 10, 5 -S/ D/ T)

Techniques, where to measure, Things to Do, Precautions

Module 03: Auditing of energy generating and using systems and equipment (C-1,L- 10,5 -S/ D/ T)

Boilers and Heat Generation; Furnaces; Steam Distribution, Usage and Condensate; Compressed Air; Motors and Transformers; Electrical Distribution and Cabling; Refrigeration; Air Conditioning; Pumps; Fans and Blowers; Cooling Towers; Heat Exchangers; DG Sets; Steam Turbines; Gas Turbines; Building Energy Systems

Module 04: Testing and Calculation (C-1, L- 10, 5 -S/ D/ T)

Learning Outcomes:

After completing this course, student should be able to:
1) Students will be able to use the energy audit methods learnt to identify the areas deserving tighter control to save energy expenditure.
2) Students will be able to carry out the cost- benefit analysis of various investment alternatives for meeting the energy needs of the organization.
3) Conceptual knowledge of the technology, economics and regulation related issues associated with energy conservation and energy auditing CO2.
4) Ability to analyse the viability of energy conservation projects CO3.
5) Capability to integrate various options and assess the business and policy environment regarding energy conservation and energy auditing CO4.
6) Advocacy of strategic and policy recommendations on energy conservation and energy auditing.

Reference Books

[1] Energy Management, Audit and Conservation" by Barun Kumar De
[2] Guide to Energy Management" by Barney L
[3] Fundamentals of Energy Conservation and Audit" by Agarkar Santosh Vyankatro and Mateti Naresh Kumar
[4] Industrial Energy Conservation (UNESCO Energy Engineering)" by Charles M Gottschalk

EN 225: ENERGY LABORATORY – II (C-4) (Any 10 Experiments)

[1] Study of solar Concentrators
[2] Study of solar hot water systems (FPC and ETC)
[3] Study of solar hot air collector/ solar dryer.
[4] Performance evaluation of box type and concentrating type solar cooker.
[5] Study of heat pipe
[6] Characteristics of SPV system.
[7] Determination of efficiency of DC/AC inverter.
[8] Study of Lead Acid Battery as a energy storage.
[9] Study of Performance of Solar pump.
[10] Flue gas analysis of petrol, diesel and LPG Engines.
[11] **a)** Find COP of 1.5 TR window / Split AC. **b)** Find COP with Heat Balance method. **c)** Effect of Condenser coding on COP of AC. **d)** Effect of desuperheater (Hot water generation)
[12] Performance ratio of grid tied PV

Learning Outcomes:

After completing this course, student should be able to:
1) supplement various topics related to energy aspects in class-room lectures to experimental setups and working.
2) The experiments based on science / engineering principles are designed to provide students enough stimulation for further investigation.
3) provide ground for the analytical subject material in a practical problem, meaning that the skills and knowledge students learn throughout the program will be applied in real renewable energy engineering work.

EN 231: DATA ANALYTICS (ELECTIVE COURSE) (4 Credits)

Module-01: Basic data & variables (C-1, L- 10, 5 -S/ D/ T)

Significance of Data, Analyzing Data, Identify Types of Data Variables, summarizing data, Identify Measures of central tendency, Describe Measures of spread, Identify Skew-ness of data distribution, Data Collection and Management Framework, Data Collection, Data Dictionary, Outlier Treatment, Missing Value Imputation. Standardization of scores, Standard Deviation, Standard Scores Data distribution, Normal Distribution, Hypothesis Testing- Developing Null and Alternative Hypotheses, Type I and Type II Errors One-Tailed Tests About a Population Mean Two-Tailed Tests About a Population Mean. Introduction to Data Structure in R

Module 02: Analysis of data (C-1.5, L- 15, 5-S/ D/ T)

What is Regression? Covariance & Correlation, features of r (correlation), Testing the significance of the correlation coefficient, Types of regression analysis, Purpose of regression analysis, Purpose of regression analysis, R2 coefficient determination, Coefficient of determination (R2) and Adjusted R2, Multiple Linear Regression, Typical Applications of Regression Analysis, Residual Analysis. Multi-collinear, Hetero-skedasticity. Case Study with R.

Logistic Regression Basics, Generalized Linear Model (glm), What is logistic regression? Types of logistic regression analysis, Applications of logistic regression analysis, Prerequisite / when & why binary logistic regression. What is clustering? , When to use cluster analysis? Application of cluster analysis, Types of cluster analysis , K means (In detail), What is decision tree? Why decision tree? Types of decision tree Constructing decision tree, Random forest and CART (In detail) Case Study with R.

Module 03: Analysis tools and programming (C-1.5, L- 15, 5 -S/ D/ T)

Introduction to analytics & different terms of analytics. Need of Analytics. Analytics vs analysis, Intelligence vs Data Science, Data Analyst Vs Business Analyst, Types of Analytics, Tools for Analytics Latest. Trends of analytics Business Analytics in Practice-Asset Health Analytics, Supply Chain Analytics, Operational Analytics, HR Analytics, Financial Analytics, Marketing Analytics, Text Analytics.

What is Time series, Components of Time Series, Techniques for forecasting- Simple Moving Average, Weighted Moving Average, Simple Exponential Smoothing, Double Exponential Smoothing, Triple Exponential Smoothing, Time Series Models Comparison, Use Cases, Industry Applications, Basic Concepts (acf, pacf, AR, MA), ARMA Model, ARIMA Model ,Industry Applications.Case Study with R

What is R? Data science & R, Components of R, Installing R, Using command line in R, Introduction to R Studio (IDE),Finding Help & solving issues in R, Data types in R, Program Structure in R, Flow Control : For loop, If condition, While conditions and repeat loop ,Debugging tools, Concatenation of Data, Combining Vars , cbind, rbind, Sapply, apply, tapply functions, Built - in functions in R, File operations in R, Reading file, Writing to a file, Importing and exporting a file, Vectors, Lists, Scalars, Data Frames, Matrices, Arrays, Factors, Use of data structures in different conditions

Learning Outcomes:
After completing this course, student should be able to:
1) Students will demonstrate proficiency with statistical analysis of data.
2) Students will develop the ability to build and assess data-based models.
3) Students will execute statistical analyses with professional statistical software.
4) Students will demonstrate skill in data management.

REFERENCE BOOKS:

1. Fundamentals of Mathematical Statistics, Gupta & Kapoor, Fourth Edition, Sultan Chand Publication
2. Time Series Analysis & Its Application, Shumway & Stuffer Fourth Edition, Springer
3. Statistical Inference, Shrivastav, First Edition, Phi
4. Design and Analysis of Experiments, Duglass C Mongtomery, Ninth Edition, Wiley
5. Hands on Programming With R, Garrett Gorelumund, First Edition, Oreilly
6. Essential of R For Data Analysis, PBR Books, First Edition, PBR Books
7. Basic Statistics, Mohonty, P.K., First Edition, Sceintific Publisher
8. Fundamental of Applied Statistics, Gupta & Kapoor , Fouth Edition, Sultan Chand & Sons
9. Basic Statistics for Business & Economics, Lind & Marchal, First Edition, Tata Mcgraw Hill
10. Operations Research, Mohonty, P.K., First Edition, Sceintific Publisher

EN 232: ADVANCED SOLAR PHOTOVOLTAIC SYSTEMS (4 Credits)
Module 01: Solar Radiation (C-1, L- 10, 5 -S/ D/ T)
Nature of Solar Radiation, Global, Beam and Diffuse Radiation, Hourly, Daily and Seasonal variation of solar Radiation, Estimation of Solar Radiation, Measurement of Solar Radiation.

Module 02: Photovoltaic Systems (C-1, L- 10, 5 -S/ D/ T)
Solar Cells and Panels, I-V curve, P-V curve, Performance of Solar Cell, Estimation of Power Obtain from Solar Power, Solar Panels PV Systems, Components of PV Systems, Performance of PV Systems, Design of PV Systems, Applications of PV Systems, Concentrating PV Systems, PV Power Plants, Power Plant with Fuel Cells

Module 03: Components and Working of Solar Photovoltaic Systems (C-1, L- 10, 5 -S/ D/ T)
Grid-connected single phase PV inverter schemes and control; power processing schemes based on single string, multi-string and ac module technologies; types of grid interface; power electronic converters used in single phase PV systems and their operation; transformer less inverters, centralized grid-connected three-phase inverters for large PV installations.
Schemes with battery energy storage (9 hrs)
Power processing schemes and control for stand-alone applications; batteries for energy storage – types, charging, battery sizing and turn-around efficiency; other types of energy storage for PV systems; grid connected schemes with standby energy storage.

Module 04: Design, Modeling and Economic Analysis of Solar Energy Systems (C-1, L- 10, 5 -S/ D/ T)
F Chart Method, φ-F Chart method, Utilizability Modeling and Simulation of Solar Energy Systems, Life Cycle Analysis of Solar Energy Systems, Time Value of Money, Evaluation of Carbon Credit of Solar Energy Systems,

Learning Outcomes:
After completing this course, student should be able to:
1) Explain the principles that underlie the ability of various natural phenomena to deliver solar energy
2) Outline the technologies that are used to harness the power of solar energy

3) Discuss the positive and negative aspects of solar energy in relation to natural and human aspects of the environment.
4) understand the different components of a solar photovoltaic systems.
5) choose type of solar PV system suitable for application.
6) design the PV array configuration, inverter and BOS components for given application.

REFERENCE BOOKS:

[1] J. A. Duffie and W.A. Beckman: Solar Engineering of Thermal Process
[2] S. A. Kalogirou: Solar Energy Engineering
[3] Biomass Renegerable Energy: D.O.hall and R.P. Overeed (John Wiley and Sons, New York, 1987)
[4] Biomass Gasification Principles and Technology, Energy technology review No. 67, - T.B. Read (Noyes Data Corp., 1981)
[5] Hydrogen and Fuel Cells: Emerging Technologies and Applications" by Bent Sørensen
[6] Hydrogen and Fuel Cells (Innovative Technologies)" by Rebecca Hirsch
[7] Handbook of Exergy, Hydrogen Energy and Hydropower Research Authors / Editors: Gaston Pélissier and Arthur Calvet
[8] Hydropower from Small and Low-Head Hydro Technologies Authors / Editors: Amanda E. Niemi and Cory M. Fincher
[9] Nuclear Energy (Tales of Invention)" by Chris Oxlade

EN 233: ADVANCED SOLAR THERMAL SYSTEMS (4 Credits)

Module 01: Solar Radiation (C-1, L- 10, 5 -S/ D/ T)

Nature of Solar Radiation, Global, Beam and Diffuse Radiation, Hourly, Daily and Seasonal variation of solar Radiation, Estimation of Solar Radiation, Measurement of Solar Radiation.

Module 02: Solar Thermal Systems (C-1, L- 10, 5 -S/ D/ T)

Flat Plate Collector, Hot Air Collector, Evacuated Tube Collector, Parabolic, Compound Parabolic and Fresnel Solar Concentrators, Central Receiver System, Thermal Analysis of Solar Collectors Performance of Solar Collectors, Solar Water Heating Systems (Active and Passive), Solar Space Heating and Cooling Systems, Solar Industrial Process Heating Systems, Solar Dryers and Desalination Systems, Solar Thermal Power Systems.

Module 03: Solar Thermals Systems and Components (C-1, L- 10, 5 -S/ D/ T)

Passive Solar Heating Systems, Active Solar Heating Systems, Solar Hot Water Systems, Concentrating Solar Collectors, Solar heat engines for electricity generation, Politics and policy.

Module 04: Designing of a Solar Thermal System for industrial process heat application. (C-1, L-10, 5 -S/ D/ T)

Components, detail design steps in designing of solar thermal system for industrial process heat application.

Learning Outcomes:

After completing this course, student should be able to:
1) Explain the principles that underlie the ability of various natural phenomena to deliver solar energy
2) Outline the technologies that are used to harness the power of solar energy
3) Discuss the positive and negative aspects of solar energy in relation to natural and human aspects of the environment.
4) learn different types of system based on intended application and technology.
5) Design a Solar Thermal System for industrial process heat application

REFERENCE BOOKS:

[1] J. A. Duffie and W.A. Beckman: Solar Engineering of Thermal Process
[2] S. A. Kalogirou: Solar Energy Engineering
[3] Biomass Renegerable Energy: D.O.hall and R.P. Overeed (John Wiley and Sons, New York, 1987)
[4] Biomass Gasification Principles and Technology, Energy technology review No. 67, - T.B. Read (Noyes Data Corp., 1981)
[5] Hydrogen and Fuel Cells: Emerging Technologies and Applications" by Bent Sørensen
[6] Hydrogen and Fuel Cells (Innovative Technologies)" by Rebecca Hirsch
[7] Handbook of Exergy, Hydrogen Energy and Hydropower Research Authors / Editors: Gaston Pélissier and Arthur Calvet
[8] Hydropower from Small and Low-Head Hydro Technologies Authors / Editors: Amanda E. Niemi and Cory M. Fincher
[9] Nuclear Energy (Tales of Invention)" by Chris Oxlade

Semester-III

Distribution of Credits and Modules

Course Code	Course Title and Modules	Credits
EN-311	**Energy Auditing and Management II**	**4**
	Module 01: Opportunities for Saving Energy	1
	Module 02: Energy Audit Management	1
	Module 03: Company Energy Policies & Monitoring, Verification and Targeting	1
	Module 04: Financial Analysis & Communication, Reporting, Training and Project Management	1
EN-312	**Assessment of Thermal Energy Systems**	**4**
	Module 01: Cogeneration and Trigeneration	1
	Module 02: Steam Boilers,Furnaces , Heat Pumps	1
	Module 03: Hot Oil,Water, Air Systems	1
	Module 04: Waste Heat Recovery	1
EN-313	**Steam Utilization**	**4**
	Module 01: Properties of Steam	1
	Module 02: Steam Distribution	1
	Module 03: Steam Heating	1
	Module 04: Steam Storage & Saving	1
EN-321	**Industrial/laboratory training (Mini Project) (Compulsory Course)**	**4**
	Elective Courses (Any One)	
EN-331	**Wind Energy Systems**	**4**
	Module 01: Wind Energy Fundamentals	1
	Module 02: Wind Turbines Technology and Components of MW series WTGs	1
	Module 03: Modern Wind Turbine Control and Monitoring System	1
	Module 04: Concept of Wind Farms and Project Cycle and Cost Economics	1
EN-332	**Waste to Energy**	**4**
	Module 01: Basics	1
	Module 02: Combustion and Gasification Technology	1
	Module 03: Pyrolysis Technology	1
	Module 04: Introduction to Energy from Waste (MSW)	1
EN-333	**Energy Storage**	**4**
	Module 01: Fundamentals of Energy Storage Systems	1
	Module 02: Types of Energy Storage Systems	1
	Module 03: Operation and Maintenance of Energy Storage Systems	1
	Module 04: Other Energy Storage Systems and Econometric Analysis of Energy Storage Systems	1

DETAIL SYLLABUS FOR SEMESTER – III

EN 311: ENERGY AUDIT AND ENERGY MANAGEMENT II (4 Credits)

Module 01: Opportunities for Saving Energy (C-1, L- 10, 5 -S/ D/ T)

Efficiency Norms for Energy Generation and Equipments using Energy.

Boilers and Heat Generation; Furnaces; Steam Distribution, Usage and Condensate; Compressed Air; Motors and Transformers; Electrical Distribution and Cabling; Refrigeration; Air Conditioning; Pumps; Fans and Blowers; Cooling Towers; Heat Exchangers; DG Sets; Steam Turbines; Gas Turbines; Building Energy Systems.

Module 02: Energy Audit Management (C-1, L- 10, 5 -S/ D/ T)

Types of Energy Audit: Walk through Audit, Detailed Audit, Investment grade; Planning for Energy Audits; Conducting the Audit: Pre-Audit Activities, Pre-Audit Visit, Actual data collection, Analysis, Draft Report, Discussion with Client; Final Report; Further Analysis; Report Submission; Role of Codes and Standards: Government Standards, Industry Association Standards, International Standards, Industry norms

Module 03: Company Energy Policy, Monitoring, Verification and Targeting (C-1, L- 10, 5 -S/ D/ T)

What, How and Where to measure; Converting Measurements into information; Assessment of Energy Conservation measures; Establishing targets.

Key Elements in a Policy; How to develop a policy; Sample Energy Policies; Organization for Energy Efficiency in a given industry: Organization Structure, Position of Energy Manager, Role, duties and authority of Energy Manager, Accounting Systems

Module 04: Financial Analysis, Communication, Reporting, Training and Project Management (C-1, L- 10, 5 -S/ D/ T)

Non-discounted and discounted cash flow methods; Sensitivity analysis; Life of a project; Risk Analysis; Risk mitigation; Financial Impact of Energy Saving; Contracting: Performance contraction, Facility Management

Communication and Reporting: Energy Reports to various levels in the organization; Internal communication of Energy related issues; External Communication

Training: Whom to train; Contents of Training: How to train

Project Management: Project Planning; Budgeting; Scheduling; Progress evaluation; Quality assurance; Commissioning; Documentation; Closure and hand over

Learning Outcomes:

After completing this course, student should be able to:

1. apply the knowledge of the subject to calculate the efficiency of various utilities.
2. design suitable energy monitoring system to analyze and optimize the energy consumption in an organization.
3. use the energy audit methods learnt to identify the areas deserving tighter control to save energy expenditure.
4. Carry out Energy Audit of the Residence / Institute/ Organization
5. Identify and evaluate energy conservation opportunities in Thermal And Electrical utilities
6. carry out the cost- benefit analysis of various investment alternatives for meeting the energy needs of the organization.
7. guide the employees of the organization about the need and the methods of energy conservation.
8. Compare energy scenario of India and World.
9. get basic preparation for BEE examination.

Reference Books

[1] Energy Management, Audit and Conservation" by Barun Kumar De

[2] Guide to Energy Management" by Barney L

[3] Fundamentals of Energy Conservation and Audit" by Agarkar Santosh Vyankatro and Mateti Naresh Kumar

[4] Industrial Energy Conservation (UNESCO Energy Engineering)" by Charles M Gottschalk

EN-312: ASSESSMENT OF THERMAL ENERGY SYSTEMS (4 Credits)

Module 01: Cogeneration and tri-generation (C-0.5, L- 05, 5 -S/ D/ T)

Definitions; Principle; Topping cycles; Bottoming Cycles; Combined cycles; Examples of each type of cycles

Module 02: Steam Boilers, Furnaces and Heat Pumps (C-0.5, L- 05, 5 -S/ D/ T)

Heat sources; Equipment types; Advantages; Disadvantages; Applications
Types of furnaces; Applications; Construction; Refractories and Insulation; Energy Balance
Types of heat pump; Principle of operation; Features; Efficiencies; Applications

Module 03: Hot oil, Water and Air Systems (C-1, L- 10, 5 -S/ D/ T)

Heat sources; Equipment types; Advantages; Disadvantages; Applications

Module 04: Waste Heat Recovery (C-1, L- 10, 5 -S/ D/ T)

Methods; Requirements; Applications; Efficiency; Problems

Learning Outcomes:

After completing this course, student should be able to:
1. explain thermal utilities and their function.
2. demonstrate and calculate energy efficiency of thermal utilities.
3. assess energy efficiency of thermal utilities
4. illustrate energy conservation opportunities in thermal utilities.
5. demonstrate best practices in thermal utilities

EN 313: STEAM UTILIZATION (4 CREDITS)

Module 01: Properties of Steam (C-0.5, L- 05, 5 -S/ D/ T)

Heating properties of steam, Power properties of steam, combined power and heating The Efficient Use of Steam

Module 02: Steam Distribution (C-0.5, L- 05, 5 -S/ D/ T)

Pipe Sizing, Insulation, Layout, Steam Quality, Steam Traps, Condensate handling, Air and its removal

Module 03: Steam Heating (C-1, L- 10, 5 -S/ D/ T)

Indirect heating, Evaporation, Direct heating, Flash steam and low-pressure vapor, Peak loads, Heat storage, Accumulators

Module 04: Steam Storage and Saving (C-1, L- 10, 5 -S/ D/ T)

Multiple effect evaporation, Steam circulation and pressurized hot water, Economizers
How to set about steam saving.

Learning Outcomes:

After completing this course, student should be able to:
1. practice the basic concepts and working cycles for steam engines.
2. design steam-based utilities.
3. identify and make different types of condensers, heat exchanges, cooling water calculations etc.
4. recommend a particular boiler as per the specified requirement.

Reference Books

[1] The Steam Engineer's Handbook: A Convenient Reference Book, for All Persons Interested in Steam Boilers, Steam Engines, Steam Turbines, and the Machinery of Power Plants (Classic Reprint)Paperback – April 18, 2018 by International Correspondence Schools (Author)
[2] A textbook on steam engineering by The International correspondence schools, Scranton, PA

EN 321: INDUSTRIAL/LABORATORY TRAINING (MINI PROJECT) (4 Credits)

The Industrial Training should be carried out in a Industry or Research Laboratory engaged in the R & D activities in Energy Field. The NGO's undertaking pilot projects in the Field of Energy can also impart training to the M. Tech student. The training shall be for a period of six weeks and student should spend approximately 60-80 hours on training. A brief report of training activities certified by authorities imparting training shall be submitted at least one month before the end of semester.
The assessment of training shall be done as follows.

1) Internal Examination 50 marks [i) Evaluation by Training Institute of Student (25 Marks), ii) Mid-Term Evaluation of Training (including Energy Awareness program) (25 Marks)]
2) Final Viva Voce Examination 50 Marks

Learning Outcomes:
After completing this course, student should be able to:
Capability to acquire and apply fundamental principles of engineering.
1) become master in one specialized technology
2) become updated with all the latest changes in technological world.
2) get ability to communicate efficiently.
3) get ability to identify, formulate and model problems and find engineering solution based on a systems approach.
4) get capability and enthusiasm for self-improvement through continuous professional development and life-long learning.
5) get awareness of the social, cultural, global and environmental responsibility as an engineer.

EN 331: WIND ENERGY SYSTEMS (ELECTIVE COURSE) (4 Credits)
Module 01: Wind Energy Fundamentals (C-1, L- 10, 5 -S/ D/ T)
Wind Energy Basics, Wind Speeds and scales, Terrain, Roughness, Wind Mechanics, Power Content, Class of wind turbines, Atmospheric Boundary Layers, Turbulence.
Wind Measurements, Analysis and Energy Estimates: Instrumentation for wind measurements, Wind data analysis, tabulation, Wind resource estimation, Betz's Limit, Turbulence Analysis
Aerodynamics Theory: Airfoil terminology, Blade element theory, Blade design, Rotor performance and dynamics, Balancing technique (Rotor and Blade), Types of loads; Sources of loads
Module2: Wind Turbines Technology and Components of MW series WTGs (C-1, L- 10, 5 -S/ D/ T)
Wind turbines types: Vertical Axis Type, Horizontal Axis, Constant Speed Constant Frequency, Variable speed Variable Frequency, Up Wind, Down Wind, Stall Control, Pitch Control, Gear Coupled Generator type, Direct Generator Drive /PMG/Rotor Excited Sync Generator
Wind Turbine Technology and Components of WTG: 1) Gear Coupled Generator Type [Const. Speed]
2) Direct Coupled Generator Type [Variable Speed Variable Frequency]: Multipole Synchronous / PMG Generators, Gear Coupled Generator Wind Turbine Components and their construction.
Electronics Sensors/Encoder/Resolvers, Wind Measurement: Anemometer and Wind Vane, Grid Synchronization System, Soft Starter, Switchgear [ACB/VCB], Transformer, Cables and assembly. Compensation Panel, Programmable Logic Control, UPS, Yaw and Pitch System: AC Drives, Safety Chain Circuits, Generator Rotor Resistor controller (Flexi Slip), Differential Protection Relay for Generator, Battery/Super Capacitor Charger and Batteries/ Super Capacitor for Pitch System, Transient Suppressor / Lightning Arrestors, Oscillation & Vibration sensing.
Direct Rotor Coupled Generator (Multipole) [Variable Speed, Variable Freq.]
Excited Rotor Synch. Generator/PMG Generator, Control Rectifier, Capacitor Banks, Step Up / Boost Converter (DC-DC Step Up), Grid Tied Inverter, Power Management, Grid Monitoring Module (Voltage and Current), Transformer, Safety Chain Circuits
Doubly Fed Induction Generator and Power Control
Module3: Modern Wind Turbine Control and Monitoring System (C-1, L- 10, 5 -S/ D/ T)
Details of Pitch System and Control Algorithms, Protections used and Safety Consideration in Wind turbines, Wind Turbine Monitoring with Error codes, SCADA and Databases: Remote Monitoring and Generation Reports, Operation and Maintenance for Product Life Cycle, Balancing technique (Rotor & Blade), FACTS control and LVRT & New trends for new Grid Codes.
Module 04: Concept of Wind Farms and Project Cycle and Cost Economics (C-1, L- 10, 5 -S/ D/ T)
Project planning, Site selection, Project execution, Operation and maintenance, Environmental concerns: Pollution free power; Noise; birds; Aesthetics; Radio waves interference; Rainfall
Cost Economics: Wind resource assessment and R & D costs, Fixed and variable costs, Value of wind energy, Life cycle costing and cash flow of wind power projects, Wind project owners / developers, Wind energy market

Learning Outcomes:
After completing this course, student should be able to:
1. get conceptual knowledge of the technology, economics and regulation related issues associated with wind and alternative sources of energy
2. get ability to analyse the viability of wind and alternative energy projects
3. get capability to integrate various options and assess the business and policy environment regarding wind and alternative energy projects
4. get advocacy of strategic and policy recommendations on usage of wind and alternative energy

REFERENCE BOOKS:

[1] Anna Mani: Wind Energy Data for India
[2] C-Wet: Wind Energy Resources Survey in India VI
[3] S. Rangrajan : Wind Energy Resources Survey in India V
[4] Sathyajith Mathew: Wind Energy
[5] Prepared by WISE: Wind Power in India (5000MW BY 2015)
[6] B.H.Khan: Non-Conventional Energy Sources

EN 332: WASTE TO ENERGY (ELECTIVE COURSE) (4 Credits)

Module 01: Basics (C-1, L- 10, 5 -S/ D/ T)

Definition of chemical and physical properties and characteristics of MSW a Fuel Comparison to conventional fuels (coal, oil, and natural gas), Resource characterization and assessment, Principles of thermochemical conversion processes: Pyrolysis,Gasification, and Combustion

Module02: Combustion and Gasification Technology (C-1, L- 10, 5 -S/ D/ T)

Description of main combustion technology, Design of combustion, Co-firing, Energy conversion systems and CHP

Description of main gasification technology, Design of gasification, Definition of synthesis gas (producer gas), Co-gasification and IGCC

Module03: Pyrolysis Technology (C-1, L- 10, 5 -S/ D/ T)

Description of main pyrolysis technology, Slow pyrolysis for char production, Fast pyrolysis for bio-oil production, Bio-oil upgrading

Module04: Introduction to Energy from Waste (MSW) (C-1, L- 10, 5 -S/ D/ T)

Characterization and classification of waste as fuel – agrobased, forest residues, industrial waste, Municipal solid waste. Waste to energy options: combustion (unprocessed and processed fuel), gasification, anaerobic digestion, fermentation, pyrolysis

Understand the properties (physical, chemical, and biological) commonly associated with Municipal Solid Waste (MSW) and integrate them into waste management calculations; MSW segregation technologies and by products; Landfill technology and limitations; Conversion devices: combustors (Spreader Stokes, Moving grate type, fluidized bed), gasifier, digesters. Briquetting technology: Production of RDF and briquetted fuel.

Properties of fuels derived from waste to energy technology: Producer gas, Biogas, Ethanol and Briquettes, Comparison of properties with conventional fuels.

Power generation using waste to energy technologies: Cl and Sl engines. IGCC and IPCC concepts.

Landfills: Gas generation and collection in landfills, Introduction to transfer stations. Comparison with non-energy options like Vermiculture, Composting.

Demonstrate an in-depth knowledge of why and how to control, collect and treat landfill gas (LFG). Appraise the parameters contributing to LFG production and composition, the risks and production controls and calculate their potential impact; Evaluate specific process parameters critical to the design of non-landfill treatment processes (e.g. thermal destruction efficiencies; flue gas desulphurization requirements); Apply process science and engineering (PSE) knowledge in describing key issues regarding emissions, treatment and performance of non-landfill technologies.

Learning Outcomes:

After completing this course, student should be able to:

1. Describe the components of solid waste management and the laws governing it.
2. Discuss solid waste collection systems, route optimization techniques and processing of solid wastes.
3. Understand the concept of pyrolysis and the production of different products by using pyrolysis.
4. Explore different types of biomass gasification techniques and understand Biochemical conversion of biomass for energy.
5. Explore different types of biomass combustion techniques and their working operations
6. Describe the basic concepts of biogas and explore Biogas plant technology and their applications.
7. Outline the design, operation, and maintenance of different methods of treatment.
8. Conclude the recent trends in reuse of solid waste

Reference Books

[1] Waste-to-Energy: Technologies and Project Implementation" by Marc J Rogoff Dr and Francois Screve.
[2] Waste to Energy Conversion Technology (Woodhead Publishing Series in Energy)" by Naomi B Klinghoffer and Marco J Castaldi
[3] Waste to Energy: Opportunities and Challenges for Developing and Transition Economies (Green Energy and Technology)" by Avraam Karagiannidis
[4] Waste to Energy" by Sethi Amrinder Singh

EN 333: ENERGY STORAGE (4 Credits)

Module 01: Fundamentals of Energy Storage Systems (C=0.5, L = 05)

Introduction and Fundamentals of energy storage, energy density, power density; Electrochemical storage components; Supercapacitors; Hydraulic storage; Flywheels; Compressed air energy storage; Pumped Hydro Storage, Transportation, mobile applications; Power electronics and grid connected systems; Grid stability and grid management, concept of load dispatch centre, effect of renewable integration in to grid. Overview of energy storage technologies: Thermal, Mechanical, Chemical, Electrochemical, Electrical. Efficiency of energy storage systems. Electrical energy storage: Batteries, Super capacitors, Superconducting Magnetic Energy Storage (SMES), charging methodologies, SoC, SoH estimation techniques. Hydrogen production and storage, fuel cells.

Module 02: Types of Energy Storage Systems (C=0.5, L=05)

Mobile storage system: electric vehicle, G2V, V2G.Hybrid Energy storage systems: configurations and applications. Storage for renewable energy systems: Solar energy, Wind energy, pumped hydro energy, fuel cells. Energy storage in Microgrid and Smart grid. Energy Management with storage systems, increase of energy conversion efficiencies by introducing energy storage.

Module 03: Operation and Maintenance of Energy Storage Systems (C=0.5, L=05)

Simulation of energy storage systems and its management, smart park, Electric Vehicle charging facility, HESS in microgrid and smart grid, microbial fuel cell, hydrogen fuel cell and so on.

Module 04: Other Energy Storage Systems and Econometric Analysis of Energy Storage Systems (C=0.5, L=05)

Performance advantages and disadvantages of lead acid batteries, Inadequacy of existing technologies, Next generation of li-based batteries, Battery Management System (BMS), Electric Vehicles battery considerations. Hybrid Charging (grid and solar photovoltaic). ROI and Project Analysis involving Energy Storage Systems.

Learning Outcomes:

After completing this course, student should be able to:
1. Discuss the scientific principles underpinning the operation of energy storage systems.
2. Resolve the intermittency of renewable energy sources such as solar and wind by utilizing problem solving skills in energy storage engineering and grid integration.
3. Work with a team to apply energy storage knowledge to develop and conduct a project.

Reference Books:

1) Energy Storage: Fundamentals, Materials and Applications by Robert A. Huggins; Springer, 2010.
2) Electric Energy Storage Systems: Flexibility Options for Smart Grids, by Pio Lombardi, PrzemyslawKomarnicki, and Zbigniew Antoni Styczynski, Springer 2017.
3) Energy Storage Systems, by S. Kakac, BirolKilkis, 1989
4) Energy Storage for Sustainable Microgrid, by David WenzhongGao, Academic Press Elsevier, 2015.
5) A.G.Ter-Gazarian, "Energy Storage for Power Systems", Second Edition, The Institution of Engineering and Technology (IET) Publication, UK, (ISBN - 978-1-84919-219-4), 2011.
6) A. R. Pendse, "Energy Storage Science and Technology", SBS Publishers & Distributors Pvt. Ltd., New Delhi, (ISBN - 13:9789380090122), 2011.

Semester-IV		
Course Code	**Course Title**	**Credits**
EN-421	Industrial / Research Project (Major Project)	**16**
Elective Courses		
EN-431	Research Paper	**04**

SYLLABUS FOR SEMESTER – IV

EN 421: INDUSTRIAL/RESEARCH PROJECT (Major Project) (16 Credits)

Industrial Project or Research Project equivalent to 16 Credits shall be completed by the student during fourth semester. A project report giving details of work done under the project should be submitted one month before the end of the semester. The project work shall be monitored by internal guide and / or a authorized / qualified person from the industry where student is doing the work.

The topic of the project and work-plan shall be approval by the internal committee formed under the chairmanship of Head / Coordinator, Centre for Energy Studies, SPPU. Mid-Term assessment and pre-submission viva-voce examination shall be compulsory to every student.

Distribution of Credits and Marks

Course Code	Course Title	Credits	Duration	Marks		Total Marks
				Internal	External	
EN 421	Industrial Project or Research Project	16	5 Months or 18-20 weeks	200	200	400

Distribution of Credits for Industrial Project or Research Project shall be as follows:

1) **Selection of Topic and Work-Plan** **:**2.0 Credits, 50 Marks
2) **Mid-Semester presentation** **:**3.0 Credits, 50 Marks
3) **Pre- Submission Presentation** **:**3.0 Credits, 100 Marks
4) **Find Viva- Voce Examination** **:**8.0 Credits, 200 Marks

Learning Outcomes:

After completing this course, student should be able to:

Capability to acquire and apply fundamental principles of engineering.

1) become master in one specialized technology
2) become updated with all the latest changes in technological world.
2) get ability to communicate efficiently.
3) get ability to identify, formulate and model problems and find engineering solution based on a systems approach.
4) get capability and enthusiasm for self-improvement through continuous professional development and life-long learning.
5) get awareness of the social, cultural, global and environmental responsibility as an engineer.

EN 431: RESEARCH PAPER (ELECTIVE COURSE) (4 Credits)

A student should publish research paper related to the project under taken during the third or fourth semester. The research paper may also be related to research area in the field of energy generation / utilization / conservation. The research paper may be also related to emerging topics in the field of energy**.**

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