SAVITRIBAI PHULE UNIVERSITY OF PUNE
(Formerly University of Pune)

Revised Syllabus for M. Tech. (Energy) 2017-18

UNDER THE FACULTY OF SCIENCE AND TECHNOLOGY

School of Energy Studies
Savitribai Phule Pune University
Pune 411 007

APRIL 2017

Savitribai Phule Pune University,
School of Energy Studies
Pune 411 007

Revised Syllabus M. Tech (Energy) 2017 onwards

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

Semester-I		**Credits**
EN-111	Energy Scenario and Energy Policy	**5**
EN-112	Fundamentals of Electrical and Mechanical Energy Systems	**5**
EN-113	Fundamental of Thermal Energy Systems	**5**
EN-114	Environmental Impact of energy systems	**5**
EN-125	Practical-I	**5**
Semester-II		
EN-211	Plant Instrumentation & Control	**5**
EN-212	Renewable Energy Technologies I	**5**
EN-213	Renewable Energy Technologies II	**5**
EN-214	Energy Audit and Management I	**5**
EN-225	Practical-II	**5**
Semester-III		
EN-311	Energy Audit and Management II	**5**
EN-312	Assessment of Thermal Energy Systems	**5**
EN-313	Steam Utilization	**5**
	Elective Papers (Any One)	**5**
EN-314	Solar PV systems and Solar Thermal Systems	
EN-315	Wind Energy Systems	
EN-316	Waste to Energy	
EN-317	Industrial/laboratory training (Mini Project)(Compulsory Course)	**5**
Semester-IV		
EN-421	Industrial project/research project	**25**

Abbreviations	
C	Credits
L	Lectures
S	Seminars
D	Discussions
T	Tutorials

Semester-I

Distribution of Credits and Modules

Course Code	Course Title and Modules	Credits
EN-111	**Energy Scenario and Energy Policy**	**5**
	Module No.1: Global Energy Scenario	1
	Module No.2: Indian Energy Scenario	1
	Module No.3: Energy Policy	2
	Module No.4: Laws relating to Energy and Environment	1
EN-112	**Fundamentals of Electrical & Mechanical Energy Systems**	**5**
	Module No.1: Basics of Electrical Energy Systems	1
	Module No.2: Motors, Transformers and Switch Gears	2
	Module No.3:Basics of Mechanical Energy Systems and Utility Systems	1
	Module No. 4: Refrigeration Systems and Air Conditioning System	1
EN-113	**Fundamentals Thermal Energy Systems**	**5**
	Module No.1: Basics of Thermodynamics	2
	Module No.2: Combustion and Heat transfer	1
	Module No.3: Heat generating equipments	1
	Module No 4: Industrial Furnaces	1
EN-114	**Environmental Impact of Energy Systems**	**5**
	Module No.1: Impact of Energy systems on Environment	1
	Module No.2: Pollution due to Thermal, Hydel and Nuclear Power Plants	2
	Module No.3: Pollution due to Vehicles and Utilities	1
	Module No 4: Environmental and Pollution Control Laws	1
EN-125	**Practical-I**	**5**

SYLLABUS FOR SEMESTER-I

EN 111: ENERGY SCENARIO AND ENERGY POLICY (5 Credits)

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

Role of energy in economic development and social transformation: Energy, GDP, GNP and its dynamics.

Energy Resources: Coal, Oil, Natural Gas, Nuclear Power and Hydroelectricity, Solar and Other renewable etc. Depletion of energy sources and impact exponential rise in energy consumption on economies of countries and on international relations.

Energy Security: Chemical and Nuclear: Non Proliferation, Energy Security, Energy Consumption and its impact on environmental climatic change.

Future Energy Options, Sustainable Development, Energy Crisis, Transition from Carbon Rich and Nuclear to Carbon Free Technologies, Parameters of Transition. Energy Intensity, IEA statistics and projections.

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

Energy Resources and Consumption: Commercial and Noncommercial Forms of Energy, Fossil Fuels, Renewable Sources, Pattern in the Past, Present and Future Projections of Consumption Pattern, Sector wise energy consumption, Impact of Energy on Economy, Development and Environment, Energy for Sustainable Development, Need for use of New and Renewable Energy Sources.

Module 03: Energy Policy (C-2, L- 10, 5 -S/ D/ T)

Energy and Environmental Policies, International Energy Policies, International Energy Treaties (Rio, Montreal, Kyoto)

Energy Policy Issues: Fossil Fuels, Renewable Energy, Power Sector Reforms, Restructuring of Energy Supply Sector, Energy Strategy for Future.

Open Access, Electricity Wheeling and Banking, Renewable Purchase Obligations (RPO), Renewable Energy Certificates (RECs), Perform Achieve and Trade (PAT scheme), Energy Certificates (E-Certs), Power exchanges and electricity trading.

National Energy Policy, Tariff policy, Hydro power policy, Renewable Energy: Present Status and future plans, Targets, Promotional activities.

Impact of Global Variations, Energy Productivity (National and Sector wise productivity).

Module 04: Laws relating to Energy and Environment (C-1, L- 10, 5 -S/ D/ T)

Energy Conservation Act-2001 and its features, Electricity Act-2003 and its features, Framework of Central Electricity Authority (CEA), Central and States Electricity Regulatory Commissions (CERC and ERCs), Electricity Tariff Setting, Emission Trading.

REFERENCE BOOKS:

[1] Energy for a sustainable world: Jose Goldenberg, Thomas Johansson, A.K.N.Reddy, Robert Williams (Wiley Eastern).

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

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

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

[5] TEDDY Year Book Published by Tata Energy Research Institute (TERI).

[6] World Energy Resources : Charles E. Brown, Springer 2002.

[7] International Energy Outlook-EIA annual Publication.

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

[9] Principles of Energy Conversion: A.W. Culp (McGraw Hill International edition).

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

EN 112: FUNDAMENTALS OF ELECTRICAL AND MECHANICAL ENERGY SYSTEMS (5 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- 10,5 -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, OpportModuleies for efficiency improvement.

Power Transformers: Principles of operation, Constructional Details, Losses, Transformer Test, Efficiency and Regulation, New type of trasnformers 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. OpportModuleies 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, OpportModuleies for efficiency improvement

Module 03: Basics of Mechanical Energy Systems and Utility Systems (C-1,L- 10,5 -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 04: Refrigeration Systems, air conditioning systems (C-1,L- 10,5 -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.

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. Liptak Chintan Book Comp /CRC Publication
[12] Analysis and design of Energy Systems- B. K. Hogde (Prentice hall 1988)
[13] Energy management and control system-Vol-I, II –M.C.Macedo (John Willy)
[14] Energy Conservation guide book Patrick/Patrick/Fardo (Prentice hall1993)
[15] Handbook on Energy efficiency.
[16] ASHRAEE Energy Use (4 Volumes),
[17] CIBSI –guide –Users Manual (U.K.
[18] Aspects of Energy Conversion : I.M.Blair and B.O.Jones
[19] Principles of Energy Conversion : A.W.Culp (McGrawHill International
[20] Energy conversion principles : Begamudre Direct Energy Conversion : W.R.Corliss and Rakoshdas
[21] Principles of Refrigeration R.J. Dossat (Wiley Estern Limited.)
[22] Efficient Use of Energy : I.E.C.Dryden (Butterworths)
[23] Instrument Engineers handbook (VolI,II,III)– B.G. Liptak Chintan Book Comp /CRC Publiation
[24] Analysis and design of Energy Systems - Hogde b.K. (Prentice hall 1988)

EN 113: FUNDAMENTALS OF THERMAL ENERGY (5 Credits)

Module 01: Basics of Thermodynamics (C-2, L- 10, 5 -S/ D/ T)

Basic Modules, Dimensions and Conversions For Energy, Concepts of Energy, Heat and Work, Ideal Gas law, 1^{st} and 2^{nd} law 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, Heat Transfer, Fuels and Fuel Treatments

Module 03: Heat generating equipments (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-1,L- 10,5 -S/ D/ T)

Furnaces, Incinerators, Dryers

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 114: ENVIRONMENTAL IMPACT OF ENERGY SYSTEMS (5 Credits)

Module 01: Impact of Energy Systems on Environment (C-2,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.

Module 02: 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 equipments 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.

Module 03: 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 hydro electric power stations on ecology and environment.

Module 04: 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.

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 Neol Brudes, A Guide to local Environmental Auditing, Earthscan Publications Ltd. (1995)

EN 125: LABORATORY COURSE-I (C-5) (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

BRIDGE COURSE: STATISTICAL TECHNIQUES AND DATA ANALYSIS

Arranging Data to Convey Meaning: Tables, Graphs and Frequency Distribution Measures of Central Tendency-Arithmetic Mean, Median, Mode, Measures of Dispersion-Range, Quartile, Mean Deviation, Standard Deviation, Coefficient of variation

Correlation: Karl Pearson coefficient and Rank correlation, Partial and Multiple Correlations. Simple and Multiple Regression (Linear), Equation and prediction

Association of Attributes: Yule's coefficient and Coefficient of colligation.

Probability: Concept, Bayes' theorem, Probability Distributions-Binomial, Poisson and Normal, Linear Programming-Formulation. Graphical solution, Transportation and Assignment Problems-all methods

Queuing Theory: Single Server (M/M/I, Infinite, FIFO) and Multi Server (M/M/C, Infinite, FIFO), Markov Chains and simulation techniques. Monte Carlo Simulation Games, Theory-2x2, zero sum game with dominance, Pure Strategy and Mixed Strategy, Decision Theory-Decision making under risk (EMV criteria) and Decision making under uncertainty, Data Analysis, Distributions, Data Presentation , Hypothesis Testing

Linear Regression Analysis: Simple, Multiple, Use of Software, R Project, MS Excel

REFERENCE BOOKS

[1] Statistical and Quantitative Methods – By Ranjit Chitale

[2] Statistical Methods - S.P.Gupta

[3] Statistics for Management - Levin and Rubin

[4] Quantitative Techniques Vol. 1 and 2 - L. C. Jhamb

[5] Statistics and Quantitative Techniques - M. G. Dhaygude

[6] Quantitative Techniques - N. D. Vohra

Semester-II

Distribution of Credits and Modules

Course Code	Course Title	Credits
EN-211	**Plant Instrumentation and Control**	**5**
	Module No.1: Basic Instrumentation System	2
	Module No.2: Basic Signal Conditioning Elements, Deflection Measurement	1
	Module No.3: Industrial Measurements	1
	Module No 4: Control Systems ,Data Storage and Transmission	1
EN-212	**Renewable Energy Technologies I**	**5**
	Module No.1: Solar Thermal and Solar Photovoltaic Energy	2
	Module No.2: Wind Energy	1
	Module No.3: Geothermal, Tidal and Wave Energy	1
	Module No.4: Industrial and Urban Waste and Waste Energy Recovery	1
EN-213	**Renewable Energy Technologies II**	**5**
	Module No.1: Bio Energy	2
	Module No.2: Nuclear Energy	1
	Module No.3: Hydrogen and Fuel Cell	1
	Module No 4: Hydel Energy	1
EN-214	**Energy Audit and Energy Management I**	**5**
	Module No.1: Instruments used for Energy Audit Measurements	2
	Module No.2: Measurement Methods for each in Audit Instrument section	1
	Module No.3: Auditing of Energy Generating and Energy using systems and Equipment	1
	Module No.4: Testing and Calculation	1
EN-225	**Practical-II**	**5**

EN 211: PLANT INSTRUMENTATION AND CONTROL (5 Credits)

Module 01: Basic Instrumentation system (C-2, 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,

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; 2 ed, 2004, Tata McGraw-Hill

[11] DVS Murthy; Transducers and Instrumentation; 2003, PHI

[12] CS Rangan, GR Sarma, and VSV Mani; Instrumentation Devices and Systems; 2 ed, Tata McGraw-Hill

[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 (5 Credits)

Module 01: Solar Thermal and Solar Photovoltaic Energy (C-2, 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-1, L- 10, 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-1, L- 10, 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.

EN 213: RENEWABLE ENERGY TECHNOLOGIES-II (5 Credits)

Module 01: Bio-Energy and Biomethanation (C-2, L- 10, 5 -S/ D/ T)

Biomass: Generation and utilization, Properties of biomass, Agriculture Crop and Forestry residues used as fuels, Biochemical and Thermo-chemical Conversion, Combustion, Gasification, Biomass gasifiers and types etc. Applications of Gasifiers to thermal power and Engines, Biomass as a decentralized power generation source for villages Concept of Bio-energy: Photosynthesis process, Bio-fuels, Biomass resources Bio based chemicals and materials Thermo-chemical Conversion: Pyrolysis, Combustion, Gasification, Liquification.

Bio-Chemical Conversion: Aerobic and Anaerobic conversion, Fermentation etc. Bio-fuels: Importance, Production and applications. Bio-fuels: Types of Bio-fuels, Production processes and technologies, Bio fuel applications, Ethanol as a fuel for I.C. engines, Relevance with Indian Economy,

Bio-based Chemicals and Materials: Commercial and Industrial Products, Biomass, Feed stocks, Chemicals, Plastics, Fibres etc. Government Policy and Status of Bio fuel technologies

Biomethanation: Importance of biogas technology, Different Types of Biogas Plants, Aerobic and anaerobic bioconversion processes, various substrates used to produce Biogas (cow dung, human and other agricultural waste, municipal waste etc.) Individual and commModuley biogas operated engines and their use. Removal of CO_2 and H_2O, Application of Biogas in domestic, industry and vehicles. Bio-hydrogen production. Isolation of methane from Biogas and packing and its utilization.

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

Potential of Nuclear Energy, International Nuclear Energy Policies and Regulations. Nuclear Energy Technologies-Fuel enrichment, Different Types of Nuclear Reactors, Nuclear Waste Disposal, and Nuclear Fusion.

Module 03: Hydrogen and fuel cell (C-1, L- 10, 5 -S/ D/ T)

Hydrogen as a renewable energy source, Sources of Hydrogen, Fuel for Vehicles. Hydrogen Production: Direct electrolysis of water, thermal decomposition of water, biological and biochemical methods of hydrogen production. Storage of Hydrogen: Gaseous, Cryogenic and Metal hydride, Fuel cell – Principle of working, construction and applications.

Module 04: Hydel Energy (C-1, L- 10, 5 -S/ D/ T)

Hydro power: Potential, Hydropower Generation and Distribution, Mini and Microhydel Power (MHP) Generation: Classification of hydel plants, Concept of micro hydel, merits, MHP plants: Components, design and layout, Turbines, efficiency, Status in India. Integrated Energy systems and their cost benefit analysis.

REFERENCE BOOKS:

[1] Biomass Renegerable Energy: D.O.hall and R.P. Overeed (John Wiley and Sons, New York, 1987)

[2] Biomass Gasification Principles and Technology, Energy technology review No. 67, - T.B. Read (Noyes Data Corp. , 1981)

[3] Wind energy Conversion Systems – Freris L.L. (Prentice Hall1990)

[4] Wind Turbine Technology: Fundamental concepts of wind turbine technology Spera D.A. (ASME Press, NY, 1994)

[5] Wind Energy Systems – G.L. Johnson (Prentice Hall, 1985)

[6] Wind Energy Explained – J.F.Manwell, J.G. McGowan and A.L. Rogers (John Wiley & Sons Ltd.)

[7] Duffle and Beckman, Solar Thermal Engineering Process, John Wiley & Sons, New York

[8] A.B. Meinel and M.B. Meinel, Applied Solar Energy, Addison – Wiley Pub. Co., Reading

[9] P.J. Lunde, Solar Thermal Engineering, John Wiley & Sons, New York

[10] H.P. Garg, Advanced in Solar Energy Technology, D. Reidel Publishing Co., Drdricht.

[11] S.P. Sukhatme, Solar Energy, Tata McGrew Hill Company Ltd., New Delhi

[12] M.A. Greaen “Solar Cells – Operating Principles, Technology, and System Applications”, 1983 Prentice Hall, Inc. New Jersey.

[13] F. Kreith and J.F. Kreider, Principles of Solar Engineering Hemisphere Publishing Coro.

[14] Chetan Singh Solanki., Solar Photovoltaic: “Fundamentals,Technologies and application”, PHI Learning Pvt., Ltd., 2009.

[15] Jha A.R., “Solar Cell Technology and Applications”, CRC Press, 2010.

[16] John R. Balfour, Michael L. Shaw, Sharlave Jarosek., “Introduction to Photovoltaics”, Jones & Bartlett Publishers, Burlington, 2011.

[17] Luque A. L. and Andreev V.M., “Concentrator Photovoltaic”,Springer, 2007.

[18] Partain L.D., Fraas L.M., “Solar Cells and Their Applications”, 2nd ed., Wiley, 2010.

EN 214: ENERGY AUDIT AND ENERGY MANAGEMENT-I (5 Credits)

Module 01: Instruments used for Energy Audit Measurements (C-2, 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 Geneartion; 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)

EN 225: LABORATORY COURSE II (C-5) (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

Semester-III

Distribution of Credits and Modules

Course Code	Course Title	Credits
EN-311	**Energy Auditing and Management II**	**5**
	Module 01: Opportunities for Saving Energy	1
	Module No.2: Energy Audit Management	1
	Module No.3: Company Energy Policies & Monitoring, Verification and Targeting	2
	Module No.4: Financial Analysis & Communication, Reporting, Training and Project Management	1
EN-312	**Assessment of Thermal Energy Systems**	**5**
	Module No.1: Cogeneration and Trigeneration	1
	Module No.2: Steam Boilers,Furnaces , Heat Pumps	2
	Module No.3: Hot Oil,Water, Air Systems	1
	Module No 4: Waste Heat Recovery	1
EN-313	**Steam Utilization**	**5**
	Module No.1: Properties of Steam	1
	Module No.2: Steam Distribution	1
	Module No 3: Steam Heating	2
	Module No 4: Steam Storage & Saving	1
	Elective Papers (Any One)	**5**
EN-314	Solar PV and Solar Thermal Systems	
EN-315	Wind Energy Systems	
EN-316	Waste to Energy	
EN-317	Industrial/laboratory training (Mini Project)(Compulsory Course)	**5**

EN 311: ENERGY AUDIT AND ENERGY MANAGEMENT II (5 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-2, 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

EN-312: ASSESSMENT OF THERMAL ENERGY SYSTEMS (5 Credits)

Module 01: Cogeneration and tri-generation (C-1, L- 10, 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-2, L- 10, 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

EN 313: STEAM UTILIZATION

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

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

Module 03: Steam Heating (C-2, 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

EN 314: SOLAR PV AND SOLAR THERMAL SYSTEMS (ELECTIVE COURSE) (5 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: Photo Thermal Systems (C-2, 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: Photovoltaic Systems (C-1, L- 10, 5 -S/ D/ T)

Solar Cells and Panels, 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 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,

REFERENCE BOOKS:

[1] J. A. Duffie and W.A. Beckman: Solar Engineering of Thermal Process
[2] S. A. Kalogirou: Solar Energy Engineering

EN 315: WIND ENERGY (ELECTIVE COURSE) (5 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

Module 2: Wind Turbines Technology and Components of MW series WTGs
(C-2, 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

Module 3: 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

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 316: WASTE TO ENERGY MANAGEMENT (ELECTIVE COURSE) (5 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

Module 02: 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

Module 03: 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

Module 04: Introduction to Energy from Waste (MSW) (C-2, 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: CI and SI 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 desulphurisation requirements)

Apply process science and engineering (PSE) knowledge in describing key issues regarding emissions, treatment and performance of non-landfill technologies.

EN 317: INDUSTRIAL/LABORATORY TRAINING (MINI PROJECT) (5 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 100 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) Evaluation by Training Institute of Student- 2.5 Credits (50 Marks)

2) Mid-Term Evaluation of Training (including Energy Awareness program)-2.5 Credits (50 Marks)

3) Final Viva Voce Examination-5 Credits (100 Mark)

EN 421: INDUSTRIAL PROJECT/RESEARCH PROJECT (25 Credits)

Industrial Project or Research Project equivalent to 25 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 Director, School of Energy Studies. Mid-Term 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	25	5 Months or 18-20 weeks	250	250	500

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

1) **Selection of Topic and Work-Plan** **:** 2.5 Credits, 50 Marks
2) **Mid-Semester presentation** **:** 5 Credits, 100 Marks
3) **Pre- Submission Presentation** **:** 5 Credits, 100 Marks
4) **Find Viva- Voce Examination** **:** 12.5 Credits , 250 Marks