# 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**

**August 2023**

**Savitribai Phule Pune University,**
**Centre for Energy Studies**
**Pune 411 007**
**Revised Syllabus for M. Tech (Energy Technology) July 2023 onwards**

The course consists of four semesters. The semester wise courses are given below.

## Program Education Objectives (PEOs)

Post Graduates will demonstrate ability to:

1. Address and tackle the real-world technological issues, develop and produce the cost-effective products, which meets the societal demands while demonstrating a strong foundation in Energy Technology.

2. Demonstrate excellence in business, higher education, and industry/technical professions while demonstrating global competitiveness.

3. Exhibit strong moral character, ethical behaviour, cooperation, transdisciplinary thinking, and the capacity to connect technical problems to broader social contexts.

## Program Outcomes (POs)

Post Graduates of Energy Technology by the time of post-graduation will demonstrate:

**PO1:** Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems one step ahead of bachelor's capability.

**PO2:** Problem analysis: Review research literature, address issues, formulate problems, and analyse them, with substantial conclusions using first principles of mathematics and technology.

PO3: Design/development of solutions: Design and develop the system and its components that satisfies the specific need with necessary safety needs.

**PO4:** Conduct investigations of complex problems: Implements the research-based knowledge and methods including design of experiments, analysis and interpretation of data.

**PO5:** Use of modern tools: Predicts the models and create methods with appropriate resources, tools and software for various activities.

**PO6:** The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

**PO7:** Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

**PO8:** Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

**PO9:** Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

**PO10:** Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

**PO11:** Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

**PO12:** Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

**Program specific outcomes**

**PSO 1:** Apply the fundamentals of mathematics, science and engineering knowledge to identify, formulate, design and investigate complex engineering problems of energy transformation, energy utilization, energy storage, and energy conservation. Understand basics and apply skills to efficient utilization of one or combinations of electrical energy, mechanical energy, thermal energy, electrochemical energy etc.

**PSO 2:** Apply the appropriate techniques and modern engineering hardware and software tools in energy engineering to engage in life-long learning and to successfully adapt in multi-disciplinary environments. Develop development of hardware/software prototypes and systems with progressive depth of complexity

**PSO 3:** Aware of the impact of professional engineering solutions in societal, environmental context, professional ethics and be able to communicate effectively.

**PSO 4:** Produce rich aspirants of energy engineers by imparting them energy engineering concepts and the practical implementation in the form of projects.

**PSO 5:** Design and analyze the novel solutions to the real life problems related to power grids, renewable energy systems, microgrids, electric vehicles, electro-mechanical devices and energy conservation, energy efficiency, and energy audit and energy management.

| Semester – I | | Credits |
|---|---|---|
| | **Major Core Credit Courses (Compulsory) [total 14 credits]** | |
| **ET-111 MJ** | Energy Policies and Regulations | 2 |
| **ET-112 MJ** | Renewable Energy Technologies – I | 2 |
| **ET-113 MJ** | Energy Audit and Management – I | 2 |
| **ET-114 MJ** | Basics of Energy System | 4 |
| **ET-121 MJP** | Energy Laboratory – I | 4 |
| | | |
| | **Major Elective Credit Courses [total 4 credits]** | |
| **ET-131 OE** | Introduction to Hydrogen as an Energy Carrier | 2 |
| **ET-132 OE** | Green Building Technologies | 2 |
| **ET-133 OE** | Skills and Practices in the Field for Energy Auditor | 2 |
| **ET-134 OE** | Environmental Impact of Energy Systems | 2 |
| **ET-135 OE** | Air Conditioning Energy Systems | 2 |
| | | |
| | **Research Methodology (Compulsory) [total 4 credits]** | |
| **EN-141 SEC** | Energy Research Methodology & Technical Writing | 4 |
| | **Total credits of semester – I** | **22** |
| **Semester – II** | | |
| | **Core Credit Courses (Compulsory) [total 14 credits]** | |
| **ET-211 MJ** | Plant Instrumentation and Control | **2** |
| **ET-212 MJ** | Challenges and Transitions in Energy Technology | 2 |
| **ET-213 MJ** | Energy Storage | 2 |
| **ET-214 MJ** | Energy Audit and Management – II | 2 |
| **ET-215 MJ** | Renewable Energy Technologies – II | 2 |
| **ET-221 MJP** | Energy Laboratory – II [ | 4 |
| | | |
| | **Major Elective Credit Courses [total 4 credits]** | |
| **ET-231 OE** | Data Analytics for Energy Systems | 2 |
| **ET-232 OE** | Electrochemical Energy Systems | 2 |
| **ET-233 OE** | Advanced Solar Photovoltaic Systems | 2 |
| **ET-234 OE** | Advanced Solar Thermal Systems | 2 |
| **ET-235 OE** | Wind Energy Technology | 2 |
| **ET-236 OE** | Electric Vehicles Basics and Charging Infrastructure | 2 |
| **ET-237 OE** | Principles and Applications of Hydrogen Storage | 2 |
| | | |
| | **Internship / On Job Training (Compulsory) [total 4 credits]** | |
| **ET-241 OJT** | Internship / On Job Training in an Energy Industry | 4 |
| | **Total credits of semester – II** | **22** |
| | | |
| | | |

| | | |
|---|---|---|
| **Semester – III** | | |
| | **Major Core Credit Courses (Compulsory) [total 14 credits]** | |
| **ET-311 MJ** | Energy Economics | 2 |
| **ET-312 MJ** | Energy Market and Regulations | 2 |
| **ET-313 MJ** | Smart Grid Energy Systems and Applications | 2 |
| **ET-314 MJ** | Steam Utilization | 4 |
| **ET-321 MJ** | Energy Systems modelling tools and | 4 |
| | | |
| | **Major Elective Credit Courses [total 4 credits]** | |
| **ET-331 OE** | Energy Audit of a Major Energy Utilizing Facility | 2 |
| **ET-332 OE** | Waste to Energy | 2 |
| **ET-333 OE** | Engineering Ethics | 2 |
| **ET-334 OE** | Energy Systems Analysis | 2 |
| | | |
| | **Research Project Credit Courses [total 4 credits]** | |
| **ET-341 OJT** | Industrial / Laboratory Research Project (Mini Project) | 4 |
| | **Total credits of semester – III** | **22** |
| **Semester – IV** | | |
| | **Major Core Credit Courses (Compulsory) [total 12 credits]** | |
| **ET-411 MJ** | Numerical Methods & Computational Techniques for Energy System Modeling | 4 |
| **ET-412 MJ** | Project Management | 4 |
| **ET-421 OJT** | Journal/Conference/Internship/MOOC | 4 |
| | | |
| | **Research Project Credit Courses [total 10 credits]** | |
| **ET-441 RP** | Industrial / Laboratory Research Project (Major Project) | 10 |
| | **Total credits of semester – IV** | **22** |

## DETAIL SYLLABUS FOR SEMESTER-I

### ET- 111 MJ : ENERGY POLICIES AND REGULATIONS (02 CREDITS)

[Note: Before teaching this syllabus, the teacher should deal with some basic concepts in Energy Policies, Principles of framing the Energy Policies, Role and Responsibilities of various stakeholders in the Energy planning of the India, impact of Energy Polices on Energy Market etc. and teach with the Case studies wherever applicable]

**Module 01: Energy Concepts, Energy Scenario in India**

Basic Concepts of Energy, Energy resources & Consumption: Commercial and noncommercial forms of energy, Fossil fuels, Renewable sources including Bio-fuels in India, their utilization pattern in the past, present and future projections of consumption pattern, Sector wise energy consumption.

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.

Discovery of various energy sources: Energy Sources and Overall Energy demand and availability, Energy Consumption in various sectors and its changing pattern, Exponential increase in energy consumption and Projected future demands.

**Module 02: Basics of Energy Economics**

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

Energy Need of Growing Economy, Role of energy in economic development and social transformation: Energy & GDP, GNP and its dynamics, Energy Intensity on Purchasing Power Parity (PPP)

**Module 03: Energy Laws and Energy Policies in India**

Energy Conservation Act of 2001, Amendments to the EC Act 2001, Role of various stakeholders for implementation of EC Act 2001,

Electricity Acts in India, Amendments to the EAct 2003 Role of various stakeholders for implementation of EAct 2003, Policies under EA 2003; Rural Electrification Policy, National Energy Policy, Tariff Policy etc.

**Module 04: Sustainable Development, Economics of Climate Change, and Energy Policy**

Concept of Sustainable Development, 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)

**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

4) Demand for Energy as a Derived Demand and energy as growth engine.

5) Policies related to economics, climate change and environmental impact.

**Reference reading:**

[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.

**ET 112 MJ: RENEWABLE ENERGY TECHNOLOGIES-I (02 CREDITS)**

**Module 01: Solar Thermal and Solar Photovoltaic Energy**

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**

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.

**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.

6) Understand the application of wind energy and wind energy conversion system.

**Reference reading:**


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.

**ET 113 MJ: ENERGY AUDIT AND MANAGEMENT – I (02 CREDITS)**

**Module - 1 Instruments for Energy Audits & their use for evaluation of utilities,**
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, Measurement methods for evaluation of utilities, Techniques for measurements, Where and how to measure. Common errors during measurements &amp,Precautions to be taken

**Module – 2 Energy Audit Methodology**
Types of energy audits – Walk through Audits, Detailed Energy Audits, Targeted Energy Audits, Cluster Audits, Investment Grade Energy Audits, Conducting the Audit: Pre Audit Activities, Pre Audit Visit, Actual data collection, Analysis,Draft Report, Discussion with Client.Types of Energy Wastages & techniques for identification of energy wastes, Overall Energy Saving calculations & Project feasibility evaluation, Final Report; Further Analysis; Report Submission, Implementation Status Monitoring, Perform Achieve Trade – Mandatory Energy Audits &amp. M&V Audits

**Module – 3 – Evaluation of Thermal Utilities**
Basic Thermal Energy Units used commonly for evaluation, Energy & Mass Balance Boilers and Heat Generation; Steam Distribution, Usage and Condensate, Furnaces & Ovens Heat Exchangers; DG Sets; Steam Turbines; Gas Turbines

**Module – 4 – Evaluation of Electrical Utilities**
Basic Electrical Energy Terms & Units used commonly for evaluation. Co-relation with mechanical and thermal units, Motors, Transformers; Electrical Distribution and Cabling Air Compressor & Compressed Air Systems , Refrigeration, Process Chillers & Air Conditioning, Pumps; Fans and Blowers, Cooling Towers, Building Energy Systems

**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 reading:**


[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

**ET 114 MJ: BASICS OF ENERGY SYSTEMS (04 CREDITS)**

**Module 01: Basics of Mechanical Energy Systems and Utility Systems**

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.

**Refrigeration Systems, air conditioning systems**

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.

**Basics of Thermodynamics**

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: Basics of Thermal Energy Systems**

Stoichiometry, HeatTransfer, Fuels and Fuel Treatments

**Heat generating equipment's**

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

**Industrial Furnaces**

Furnaces, Incinerators, Dryers

**Module 03: Basics of Electrical Energy System**

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.

**Motors, Transformers and Switch Gears**

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) 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

5) students should be able to use fundamental principles of fluid mechanics to solve thermal problem.

6) use basic principles of thermodynamics to solve thermal problem.

7) use basic principles of heat transfer and mass transfer to solve thermal problem.

8) gain knowledge of advanced features of fluid mechanics, thermodynamics, heat and momentum transfer pertaining to thermo-fluid problem,

9) 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.

10) Fundamental of electrical energy systems and its components. Conversion of electric and magnetic fields.

11) Kirchhoff's law and its relevance to electrical energy.

12) Electrical network analysis and star-delta and delta star transformation.

13) Power factor and phasor representation of alternating quantities.

14) Fundamentals of motors and switchgears

15) Selection and sizing of AC synchronous, AC induction, and DC motors.

**Reference reading:**


**[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]** Handbook on Energy efficiency.
**[6]** ASHRAEE Energy Use (4 Volumes),
**[7]** Principles of Energy Conversion: A.W.Culp ( McGrawHill International
**[8]** Principles of Refrigeration R.J. Dossat (Wiley Estern Limited.)
**[9]** Efficient Use of Energy: I.E.C.Dryden (Butterworths)
**[10]** Analysis and design of Energy System

**ET 121MJP: ENERGY LABORATORY (04 CREDITS)**

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.

## MAJOR ELECTIVE CREDIT COURSES SEM I [TOTAL 4 CREDITS]

## ET 131 OE: INTRODUCTION TO HYDROGEN AS AN ENERGY CARRIER (02 CREDITS)

**Module 1**: **Properties of hydrogen**,

Thermodynamics properties, Hydrogen as fuel,energy content, comparison with other fuels. global status of supply and demand, economic analysis of hydrogen as fuel.

**Module 2**: **Commercial Methods of hydrogen production** :

Steam reforming : fundamentals of steam reforming, advanced methods of steam reforming, partial oxidation, autothermal reforming, combined reforming, reforming using alternate energy sources, hydrogen production from methane, coal and biomass.

Electrolysis : fundamentals for electrolysis of water, components of electrolytic cell, configuration of electrolyser stack, different electrolyser technologies,

Other technologies : Overview of Photoelectrochemical, electrochemical, biochemical , high temp water splitting , thermochemical cycles for hydrogen production, technical and economic comparison of different production methods and global status of production methods.

**Module 3: Hydrogen processing & storage**

Introduction to hydrogen separation and purification ,storage, fundamentals of hydrogen compression and expansion, mechanical and non-mechanical hydrogen compressors, compressed hydrogen tank types, hydrogen liquefaction, liquid state hydrogen storage tanks, fundamentals of hydrogen storage in adsorption-based materials, metal hydrides, types of metal hydrides, metal hydride-based systems, novel materials for solid state hydrogen storage, long distance hydrogen transport via pipelines, ships and in form of LOHC, hydrogen transport via road; hydrogen refuelling stations.

**Module 4: Hydrogen handling & safety**

Properties of hydrogen associated with hazards, classification of hydrogen hazards, compressed and liquid hydrogen related hazards, regulation, codes and standards, utilization of hydrogen in various sectors, global status and future directions.

**Learning Outcomes:**

After completing this course, student should be able to:

1. Know about the characteristic properties of hydrogen as fuel.
2. Understand the basic concepts of hydrogen production by reforming
3. Understanding electrolysis processes, hydrogen electrolyser principles
4. Ways of processing ,transporting and storing hydrogen
5. Hydrogen safety, Understand the hazards of handling, storage, transportation etc.

**Reference reading:**


1. Hydrogen Fuel-Production, Transport, and Storage, edited by Ram B. Gupta, CRC Press, Taylor & Francis Group, 2009, ISBN - 978-1-4200-4575-8.
2. Fuel Cell Fundamentals by Ryan O'hayre, Suk-Won Cha, Whitney G. Colella, and Fritz B. Prinz, 2016, John Wiley & Sons, Inc. ISBN – 978-1-1191-1420-8.
3. Hydrogen Storage: State-Of-The-Art and Future Perspective by E. Tzimas, C. Filiou, S.D. Peteves and J.-B. Veyret, European Communities, 2003, ISBN - 92-894-6950-1.
4. Global Hydrogen Review 2021, IEA Publications, 2021, www.iea.org.
5. Hydrogen Production by Electrolysis, edited by Agata Godula-Jopek, Wiley-VCH Verlag GmbH & Co, 2015, ISBN - 978-3-527-67653-8.
6. Handbook of Hydrogen Storage - New Materials for Future Energy Storage, Edited by Michael Hirscher, Wiley-VCH Verlag GmbH & Co, 2010, ISBN - 978-3-527-32273-2.


## ET 132 OE: GREEN BUILDING TECHNOLOGIES (02 CREDITS)

**Module 1: Introduction to Green Buildings:**

Definition of green buildings and sustainable development, typical features of green buildings, benefits of green buildings towards sustainable development. Green building rating systems – GRIHA, IGBC and LEED, overview of the criteria as per these rating systems.

**Module 2: Site selection and planning:**

Criteria for site selection, preservation of landscape, soil erosion control, minimizing urban heat island effect, maximize comfort by proper orientation of building facades, day lighting, ventilation, etc. Water conservation and efficiency: Rainwater harvesting methods for roof & non-roof, reducing landscape, water demand by proper irrigation systems, water efficient plumbing systems, water metering, waste water treatment, recycle and reuse systems.

**Module 3: Energy Efficiency**

Environmental impact of building constructions, Concepts of embodied energy, operational energy and life cycle energy. Methods to reduce operational energy: Energy efficient building envelopes, efficient lighting technologies, energy efficient appliances for heating and air-conditioning systems in buildings, zero ozone depleting potential (ODP) materials, wind and solar energy harvesting, energy metering and monitoring, concept of net zero buildings.

**Module 4: Building materials**

Methods to reduce embodied energy in building materials: (a) Use of local building materials (b) Use of natural and renewable materials like bamboo, timber, rammed earth, stabilized mud blocks, (c) use of materials with recycled content such as blended cements, pozzolana cements, fly ash

bricks, vitrified tiles, materials from agro and industrial waste. (d) reuse of waste and salvaged materials. Waste Management: Handling of construction waste materials, separation of household waste, on-site and off-site organic waste management Indoor Environmental Quality for Occupant Comfort and Wellbeing: Daylighting, air ventilation, exhaust systems, low VOC paints, materials & adhesives, building acoustics. Codes related to green buildings: NBC, ECBC, ASHRAE, UPC etc.

**Learning outcome:**

After completing this course, student should be able to:

1) Know about the Concepts of Green Buildings

2) Site Selection and Planning

3) Methods to reduce operational Energy for efficient use of Energy

4) Basic understanding of building materials

5) Understanding standards and codes for Green Buildings

Reference Books:

1. IGBC Green Homes Rating System, Version 2.0., Abridged reference guide, 2013, Indian Green Building Council Publishers.

2. GRIHA version 2015, GRIHA rating system, Green Rating for Integrated Habitat Assessment.

3. Alternative building materials and technologies by K.S. Jagadish, B.V. Venkatarama Reddy and K.S. Nanjunda Rao.

4. Non-Conventional Energy Resources by G. D. Rai, Khanna Publishers.

5. Sustainable Building Design Manual, Vol.1 and 2, TERI, New Delhi 2004.

6. Mike Montoya, Green Building Fundamentals, Pearson, USA, 2010.

7. Charles J. Kibert, Sustainable Construction – Green Building Design and Delivery, John Wiley & Sons, New York, 2008.

8. Regina Leffers, Sustainable Construction and Design, Pearson / Prentice Hall, USA, 2009.

**ET 133 OE: SKILLS AND PRACTICES IN THE FIELD FOR ENERGY AUDIT (02 CREDITS)**

**Module 01: Skills and responsibilities of an energy auditor:**

Focus on conserving energy and reducing carbon and environmental footprints, calculating the amount of energy conservation, safety concerns arising due to projects,

**Module 02: Conducting Energy Audits, skills for energy audit**,

Certification Collecting Energy Usage information from various sources, energy saving solutions, monitoring energy consumption, use of alternative energy sources and energy saving devices, technical feasibility, preparing audit reports etc.

**Learning Outcomes:**

1) After completing this course, student should be able to:

2) Make the feasibility study of energy audits, performing energy audit, suggest energy conservation measures and provide energy conservation solutions

**References:**

Book published by Bureau of Energy Efficiency

**[1]** Energy Efficiency in Electrical Utilities
**[2]** General Aspects of Energy Management & Energy Audit
**[3]** Energy Efficiency in Thermal Utilities
**[4]** Energy Performance Assistance for Equioment And Utility Systems
**[5]** Handbook of Energy Audits by Albert Thumann , Terry Niehus (Author), William J. Younger (Author)

**EN 134 OE: ENVIRONMENTAL IMPACT OF ENERGY SYSTEMS (02 CREDITS)**

**Module 1: Impact of Energy Systems on Environment**

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 2: Pollution due to Thermal, Hydel and Nuclear Power Plants**

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.

**Module 3: Pollution due to Vehicles and Utilities**

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.

**Module 4: Environmental and Pollution Control Laws**

United 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 reading:**


**[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)


## ET 135 OE: AIR CONDITIONING ENERGY SYSTEMS (02 CREDITS)

**Module 1 Air conditioning systems**

Introduction to air conditioning system and its applications, conventional air conditioning system, solid desiccant air conditioning system, liquid desiccant air conditioning system, desiccant coated air conditioning system, renewable energy driven air conditioning system.

**Module 2: Design guidelines of air conditioning systems**

Cooling and heating load calculations, selection of suitable air conditioning system for different climate zones.

**Learning Outcome:**

1. Familiarizing the basic understanding of air conditioning and ventilation systems.
2. Getting trained on analytical/thermal models and design guidelines related to air conditioning and ventilation systems.
3. To present engineering solutions to the problems encountered in practical applications.
4. Providing a glance at consultancy works, start-ups, and research topics related to air conditioning and ventilation systems.
5. To study the Environmental and sustainability aspects of air conditioning and ventilation systems.

**Reference reading:**


1. D.J. Croome and B.M. Roberts, *Air conditioning and ventilation of buildings*, Pergamon Press
2. W.P. Jones, *Air Conditioning Engineering*, Butterworth Heinemann, 2001
3. Xiaohua Liu, Yi Jiang, Tao Zhang, *Temperature and Humidity Independent Control (THIC) of Air-conditioning System*, Springer
4. W.F. Stoecker & J.W. Jones, *Refrigeration and Air Conditioning*, McGraw-Hill


**EN 141 SEC: ENERGY RESEARCH METHODOLOGY & TECHNICAL WRITING (04 CREDITS)**

**1) Foundation of Research:** Meaning, Objectives, Motivation, Utility. Concept of theory, empiricism, deductive and inductive theory. Characteristics of scientific method -understanding the language of research Concept, Construct, definition, Variable. Research Process
**2)Problem Identification & Formulation:** definition and formulating the research problem, Necessity of defining the problem, Importance of literature review in defining a problem, Research Question - Investigation Question - Measurement Issues – Hypothesis Qualities of a good hypothesis - Null hypothesis & Alternative Hypothesis. Hypothesis Testing - Logic & importance
**3) Research Design:** Concept and Importance in Research - Features of a good research design - Exploratory Research Design - Concept, Types and uses, Descriptive Research Design - concept, types and uses. Experimental Design - Concept of Independent & Dependent variables.
**4) Qualitative and Quantitative Research:** Qualitative - Quantitative Research - Concept of measurement, causality, generalization, replication. Merging the two approaches.
**5) Data Collection and analysis:** Execution of the research - Observation and Collection of data - Methods of data collection, hypothesis-testing - Generalization and Interpretation.
**6) Measurement:** Concept of measurement - what is measured? Problem in measurement in research - Validity and Reliability. Levels of measurement - Nominal, Ordinal, Interval, Ratio.
**7) Sampling:** Concept of Statistical population, Sample, Sampling Frame, Sampling Error, Sample size, Non Response. Characteristics of a good sample. Probability Sample, Simple Random Sample, Systematic Sample, Stratified Random Sample & Multi-stage sampling. Determining size of the sample - Practical considerations in sampling and sample size.
**8) Data Analysis**: data Preparation - Univariate analysis (frequency tables, bar charts, pie charts, percentages), Bivariate analysis - Cross tabulations and Chi-square test including testing hypothesis of association.
**9) interpretation of Data and Paper Writing:** Layout of a Research Paper, Journals in Energy Studies , Impact factor of journals, When and where to publish? Ethical issues related to publishing, Plagiarism and Self-Plagiarism.Use of Encyclopedias, Research Guides, Handbook etc., Academic databases for concerned discipline . Use of tools / techniques for Research: methods to search required information effectively, Reference Management Software like Zotero/mendeley, Software for paper formating like LaTeX/MSOffice, software for detection of Plagiarism.

**10) Reporting and Thesis writing:** Structure and components of scientific reports - Types of report - Technical reports and thesis - Significance - Different steps in the preparation -Layout, Structure and Language of typical reports - Illustrations and tables - Bibliography, referencing and footnotes - Oral presentation - Planning - Preparation - Practice - Making presentation - Use of visual aids - Importance of effective communication

**11) Application of results and ethics:** Environmental impacts - Ethical issues – ethical committees - Commercialization - Copy right - royalty - Intellectual property rights and patent law - Trade related aspects of intellectual property Rights - Reproduction of published material - Plagiarism - citation and acknowledgement - citation and acknowledgement - Reproducibility and accountability.

**12) Reasoning and Mentalability:** Analogy, Classification, Series, Coding-Decoding, Direction Sense, Representation Through Venn Diagrams, Mathematical Operations, Arithmetical Reasoning, Inserting the Missing Character, Number, Ranking and Time Sequence Test, Eligibility Test, Representation through Venn-diagrams, Number & symbols ordering, Comprehension questions, Statement & assumptions, Statement & conclusions, Statement & actions

**Learning Outcome:**

1) Understanding Research foundation, Identification of problems, formulations, research design, Measurement, sampling and data analysis,
2) Research paper and Thesis writing

**Reference reading:**


1) Research Methodology - C. R. Kothari
2) Research Methodology: An Introduction - Stuart Melville and Wayne
3) Practical Research Methods - Catherine Dawson
4) Select references from the Internet
5) Garg, B. L., Karadia, R., Agarwal, F. and Agarwal, U. K., 2002. An introduction to Research Methodology, RBSA Publishers.
6) Kothati , C.R., 1990. Research Methodology: Methods and Techniques. New Age International. 418p.
7) Sinha, S. C. and Dhiman, A. K., 2002. Research Methodology, Ess Ess Publications. 2 columes.
8) Trochim, W. M. K., 2005. Research Methods: the concise knowledge base, Atomic Dog Publishing. 270p
9)Wadehra, B. L. 2000. Law relating to patents, trademarks, copyright designs and geographical indications. Universal Law Publishing.

## SYLLABUS FOR SEMESTER II

## ET- 211 MJ: PLANT INSTRUMENTATION & CONTROL [02 CREDITS]

[Note: Before teaching this syllabus, the teacher should deal with some basic concepts in recent trends and basis for various relevant policies in energy sector]

**Module 01: Basic Instrumentation system**

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**

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**

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**

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 reading:**


**[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


## ET 212 MJ: CHALLENGES AND TRANSITIONS IN ENERGY TECHNOLOGY [2 CREDITS]

The energy transition is the shift from fossil fuels to low carbon and renewable energy sources. It is a significant structural change in the energy system that affects supply, demand, energy mix and prices. It aims to avoid the negative impacts of fossil fuels on the climate and the environment, and to access more sustainable and abundant sources of energy.

India is now committed to the energy transition of decarbonization and achieving a state of net zero emission. India has made remarkable progress in recent years. At COP26, India announced the highly ambitious goal of decarbonizing energy to 50% and achieving 500 GW of fossil fuel free generating capacity by 2030.

**Module 01: Energy Transition Planning**

Need of Energy Transition, India's voluntary Targets for Energy Transition, Long term Demand-Supply Forecasting for Energy Transition Planning, Self–reliance, energy efficiency and environmental sustainability are the key drivers of India's energy transition, Resource Adequacy, Integrated Resource Planning for energy transition

**Module 02: Energy Transition Technologies**

Technological Advancement driving Energy Transition, Distributed Renewable Energy Technologies, Off-Shore wind power generation, Energy Storage Technologies, Electric Vehicle Charging Infrastructure, Green Hydrogen, Fuel shifting of existing thermal power plants to reduce the $CO_2$ emission of Thermal Power Plant, Net Zero Technologies, Role of Nuclear Energy Technologies in Energy Transition

**Module 03: Policy and Regulatory Enablers for India's Energy Transition and Challenges**

National electricity policy 2021, National electricity Plan, Draft National Energy Policy,2040, Central Electricity Authority's Resource Adequacy Planning Guidelines, India's Net Zero Goal by 2070, Industrial Decorbonisation policies, Aatma Nirbhar Bharat Policy for supporting domestic manufacturing and ensuring ecosystem support for energy transition, challenges of Energy Transition.

**Learning Outcome:**

1} To do the systematic planning of Energy Transition

2) Understand various technologies considered for Energy Transition

3) Policies and regulations for undergoing energy transition.

**Reference Reading:**


**[1]** International Energy Markets: Understanding Pricing, Policies, and Profits. 2nd Edition. Carol A. Dahl. PennWell.
**[2]** Energy Economics: Theory and Applications Peter Zweifel, Aaron Praktiknjo, Georg Erdmann Springer, 27-Mar-2017
**[3]** Energy for a sustainable world: Jose Goldenberg, Thomas Johansson, A.K.N.Reddy, Robert Williams (Wiley Eastern).
**[4]** Energy policy: B.V. Desai (Weiley Eastern).
**[5]** Modeling approach to long term demand and energy implication: J. K. Parikh.
**[6]** Energy Policy and Planning:B.Bukhootsow.
**[7]** TEDDY Year Book Published by Tata Energy Research Institute (TERI).
**[8]** World Energy Resources: Charles E. Brown, Springer 2002.
**[9]** International Energy Outlook-EIA annual Publication.
**[10]** Heat and Thermodynamics – M.W. Zemansky (McGraw Hill Publication).


**ET 213 MJ: ENERGY STORAGE [02 CREDITS]**

**Module 01: Fundamentals of Energy Storage Systems**

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**

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**

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**

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 reading:**

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, Przemyslaw Komarnicki, 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.

**ET 214 MJ: ENERGY AUDIT AND MANAGEMENT – II [02 CREDITS]**

**Module 01: Energy Saving Opportunities & Case Studies – Thermal Utilities**

Efficiency norms, Standards for thermal equipment like boilers, Waste Heat Recovery, Heat Loss Reduction for Energy Savings, Case Studies for Thermal Utilities

**Module 02: Energy Saving Opportunities & Case Studies – Electrical Utilities**

Efficiency Norms and Benchmark data, Energy Savings in Motors, Transformers, Electrical Distribution and Cabling, Energy Savings in Air Compressor & Compressed Air Systems, Energy Savings in Refrigeration, Process Chillers & Air Conditioning, Energy Savings in Pumps; Fans and Blowers, Energy Savings in Cooling Towers, Energy Savings in Building Energy Systems

**Module 03: Energy Action Planning**

Financial Analysis of Energy Projects, Cash Flow & Simple financial Analysis by payback period & ROI analysis, Discounted cash flow methods with NPV & IRR calculation, Energy Service Companies (ESCO) & Performance contracting, Risk & Sensitivity Analysis for Energy related projects, Training & Communications for Energy Management, Energy Reports to various levels in the organization, Internal communication of Energy related issues; External Communication, Energy Management Training: Whom & How to train; Contents of Training, Project Planning, Budgeting, Scheduling, Progress evaluation, Quality assurance, Commissioning, Documentation, Closure and hand over, Life of project

**Module 04: Energy Monitoring and Targeting**

Organization for Energy Efficiency in a given industry: Organization Structure, Position of Energy Manager, Role, duties and authority of Energy Manager, Accounting Systems, Continuous Energy Monitoring: What, How and Where to measure; Converting Measurements into information; Assessment of Energy Conservation measures, Relation between production and energy. Establishing targets. Key Elements in a Policy; How to develop a policy; Sample Energy Policies; Facility Management & Maintenance for Energy Saving, ISO 50001 – Overview of ISO 50001, Introduction to clauses, Steps for implementation of ISO 50001 in an organisation

**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 reading:**


[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


**ET 215 MJ: RENEWABLE ENERGY TECHNOLOGIES – II [02 CREDITS]**

**Module 01: Geothermal, Tide and Wave Energy**

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 02: Bio Energy, Industrial and Urban Waste & Waste Energy Recovery**

Bio Mass, Biogas & Technologies, 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) Analyze how industrial and urban waste and waste energy recovery is done.

**Reference reading:**


1. "Geothermal Energy: An Alternative Resource for the 21st Century" by Harsh K. Gupta and Sukanta Roy (Elsevier, 2007).
2. "Geothermal Energy: Utilization and Technology" by Arnold Watson and David N. Chapman (Taylor & Francis, 2000).
3. "Tidal Energy: Resource Assessment and Exploitation" by AbuBakr S. Bahaj (Woodhead Publishing, 2012).
4. "Ocean Wave Energy: Current Status and Future Prespectives" by Michael E. McCormick (Springer, 2008).
5. "Bioenergy: Principles and Applications" by Yebo Li and Samir Kumar Khanal (Wiley, 2013).
6. "Bioenergy: Biomass to Biofuels" by Anju Dahiya (Academic Press, 2014).
7. "Waste to Energy Conversion Technology" by Naomi B Klinghoffer and Marco J Castaldi (CRC Press, 2013).
8. "Waste-to-Energy: Technologies and Project Implementation" by Marc J. Rogoff, Francois Screve, and Rosemarie Stidham (CRC Press, 2010).


**ET 221 MJP: ENERGY LABORATORY – II [02 CREDITS]**

**[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.

## MAJOR ELECTIVE CREDIT COURSES [TOTAL 4 CREDITS]

### ET 231 OE: DATA ANALYTICS FOR ENERGY SYSTEMS [02 CREDITS]

**Module-01: Basic data & variables**

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**

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**

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 reading:**


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

**ET 232 OE: ELECTROCHEMICAL ENERGY SYSTEMS [02 CREDITS]**

**Module 1: Background Theory**

Origin of potential – electrical double layer – reversible electrode potential – standard hydrogen electrode – emf series – measurement of potential – reference electrodes (calomel and silver/silver chloride) indicator and ion selective electrodes – Nernst equation – irreversible processes – kinetic treatment – ButlerVolmer equation – Overpotential, activation, concentration and IR overpotential – its practical significance – Tafel equation and Tafel plots – exchange current density and transfer coefficients.

**Module 2: Batteries**

Primary batteries : The chemistry, fabrication and performance aspects, packing classification and rating of the following batteries: (The materials taken their function and significance, reactions with equations, their performance in terms of discharge, capacity, and energy density to be dealt with). Zinc-carbon (Leclanche type), zinc alkaline (Duracell), zinc/air, zinc-silver oxide batteries; lithium primary cells – liquid cathode, solid cathode and polymer electrolyte types and lithium-ferrous sulphide cells (comparative account).

Secondary batteries : ARM (alkaline rechargeable manganese) cells, Lead acid and VRLA (valve regulated (sealed) lead acid), nickel-cadmium, nickel-zinc, nickelmetal hydride batteries, lithium ion batteries, ultra thin lithium polymer cells (comparative account). Advanced Batteries for electric vehicles, requirements of the battery – sodium-beta and redox batteries.

**Module 3: Reserve batteries and Fuel cells**

Reserve batteries – water activated, electrolyte activated and thermally activated batteries – remote activation – pyrotechnic materials. Fuel Cells:Principle, chemistry and functioning – carbon, hydrogen-oxygen, proton exchange membrane (PEM), direct methanol (DMFC), molten carbonate electrolyte (MCFC) fuel cells and outline of biochemical fuel cells.

Electrochemical Processes: Principle, process description, operating conditions, process sequence and applications of Electroforming – production of waveguide and plated through hole (PTH) printed circuit boards by electrodeposition; Electroless plating of nickel, copper and gold; Electropolishing of metals; Anodizing of aluminium; Electrochemical machining of metals and alloys.

**Reference reading:**


1. Derek Pletcher and Frank C. Walsh, “Industrial Electrochemistry”, Blackie Academic and Professional, (1993).
2. Dell, Ronald M Rand, David A J, “Understanding Batteries”, Royal Society of Chemistry, (2001)
3. Christopher M A, Brett, “Electrochemistry – Principles, Methods and Applications”, Oxford University, (2004).
4. Watanabe T, “Nano-plating: microstructure control theory of plated film and data base of plated film microstructure”, Elsevier, Oxford, UK (2004).

5. Kanani N, “Electroplating and electroless plating of copper and its alloy”, ASM International, Metals Park, OH and Metal Finishing Publications, Stevenage, UK (2003).
6. Lindon David, “Handbook of Batteries”, McGraw Hill, (2002).
7. Curtis, “Electroforming”, London, (2004).
8. Rumyantsev E and Davydov A, “Electrochemical machining of metals”, Mir, Moscow, (1989)

**ET 233 OE: ADVANCED SOLAR PHOTOVOLTAIC SYSTEMS [02 CREDITS]**

**Module 01: Solar Radiation**

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**

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**

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**

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 reading:**


[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 234 OE: ADVANCED SOLAR THERMAL SYSTEMS [02 CREDITS]**

**Module 01: Solar Radiation**

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**

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**

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.**

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 reading:**


**[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


**ET 235 OE: WIND ENERGY TECHNOLOGY [02 CREDITS]**

**Module 01: Wind Energy Fundamentals**

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**

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] 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**

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**

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 reading:**

**[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

**ET 236 OE: ELECTRIC VEHICLES BASICS AND CHARGING INFRASTRUCTURE [02 CREDITS]**

**Module 01: Introduction to Electric Vehicles and Types of EV Chargers:**

History of EV, Components of Electric Vehicle, Comparison with Internal combustion Engine : Technology, Comparison with Internal combustion Engine: Benefits and Challenges, EV classification and their electrification levels., EV Terminology, Electric Vehicle Technology and Charging Equipment, Basic charging Block Diagram of Charger, Difference between Slow charger and fast charger, Slow charger design rating, Fast charger design rating, AC charging and DC charging, Onboard and off board charger specification, Type of Mode of charger Mode -2 , Mode-3 and Mode-4, EVSE associated charge times calculation.

**Module 02: Selection and sizing of fast and slow charger (AC & DC):** AC Pile Charger, DC Pile Charger, EVSE Power Module selection and technical specification, Selection of EVSE Communication Protocol (PLC / Ethernet / Modbus/ CAN Module ), Communication gateway, Specification of open charge point protocol (OCCP 1.6/2.0), Bharat DC001 & AC001 Charger specification, Communication Interface between charger and CMS ( central management system), Payment apps

**Module 03: Selection and sizing of Common types of connectors and applications:** Selection of AC charger type-1 , type -2 and type -3, Communication between AC charger and EV, Selection of DC charger connector GB/T, CHAdeMO , CCS-1 and CSS-2, Communication methodology of DC fast chargers, IS/ IEC/ARAI/ standard of Charging topology ,Communication and connectors (IEC 61851-1, IEC 61851-24,62196-2 ), Selection sizing of Charger connector cable.

**Public Charging infrastructure / Electrical system design:** Assessment of site Location for Public charging station, Selection and Sizing of Distribution transformer, Selection and sizing of HT Equipment ( VCB , CT , PT , Metering ), Selection and Sizing HT Cables and LT cables, Selection and sizing of Distribution Board / feeders, Sizing calculation of LT and HT cable, Selection and of Compact Substation (CSS for EV CS)/ Power Substation), Selection of relay and calculation.

**Module 04: Preparation and Technology of EV Chargers:** Preparation of EV Charger Electric, Assessment of site Location for Public charging station, Selection and Sizing of Distribution transformer, Selection and sizing of HT Equipment ( VCB , CT , PT , Metering ), Selection and Sizing HT Cables and LT cables, Selection and sizing of Distribution Board / feeders, Sizing calculation of LT and HT cable,

Selection and of Compact Substation (CSS for EV CS)/ Power Sub station), Selection of relay and calculation, Preparation of EV Charger Single Line Diagram, Preparation of EV Charger Electric,

**EV Charger Integration with Solar Power Plant:** Selection of PV module technology, Comparison between PV module technology, Comparison between solar power plant energy output, Selection and Sizing inverter, Selection and sizing of Cable and Earthing,

**Learning Outcome:**

1)To understand basics of hybrid electric vehicle

2) To understand drives and control.

3) To Select battery, battery indication system for EV applications

4) Design battery charging stations for an EV

**Reference Reading:**

1) Electric and Hybrid Vehicles, 1st Edition, by Tom Denton, Routledge Publishers, 2016

2) Electric Vehicles: And the End of ICE age, by Anupam Singh, Adhyyan Books Publisher, 2019

3) Electric Vehicle Technology Explained, 2nd Edition, by James Larminie, and John Lowry, Wiley, Publisher, 2012

4) Electric Vehicle Battery Systems, by Sandeep Dhameja, Elsevier Publisher, 2012

5) Reference Standards: IEC IEC 60068-2 (1,2,14,30),IEC 61683,IEC 60227,IEC 60502 IEC 60947 part I,II, III ,IEC 61215

**ET 241 OJT: INTERNSHIP / ON JOB TRAINING IN AN ENERGY INDUSTRY [4 CREDITS]**