ACADEMIC REGULATIONS

COURSE STRUCTURE AND

DETAILED SYLLABUS

Centre for Energy Studies

For

M. Tech. (Energy Systems)

(Two Year **Full Time** Program)

JNTUH COLLEGE OF ENGINEERING HYDERABAD

(Autonomous)

Kukatpally, Hyderabad-500085, Telangana, India.

2021

Course Scheme for M. Tech. (Energy Systems)

M. Tech., Sem-I

Course Number	Subject	Scheme of Studies Per Week			Credits
		L	T	P	
1ES01	Program Core-I Renewable Energy Technologies	3	0	0	3
1ES02	Program Core-II Engineering Heat transfer	3	0	0	3
1ES11	Program Elective I Thermal and Nuclear Power Plants Energy Efficient Buildings / Waste Management and Recycling	3	0	0	3
1ES12	Program Elective II Measurement Systems in Energy Engineering Applied Thermodynamics / Environmental Pollution and Control	3	0	0	3
1A111	Research Methodology and IPR	2	0	0	2
1A112	Audit Course- I English for Research Paper Writing	2	0	0	0
1ES03	Laboratory 1 (Based on Core) Renewable Energy Conversion Laboratory	0	0	4	2
1ES04	Laboratory 2 (Based on Elective) Energy Computational laboratory	0	0	4	2
	Total	**16**	**0**	**8**	**18**
Total Credits: 18					

M. Tech., Sem-II

Course Number	Subject	Scheme of Studies Per Week			Credits
		L	T	P	
2ES05	Program Core III Direct Energy Conversion	3	0	0	3
2ES06	Program Core-IV Energy Conservation in Thermal Systems	3	0	0	3
2ES13	Program Elective III- Energy Efficiency in Electrical Utilities / Nuclear Power Plants / Modern Control systems	3	0	0	3
2ES14	Program Elective IV- Optimization of Energy Systems / Wind Energy Conversion Systems /	3	0	0	3

	Solar Energy Applications				
2A113	Audit Course - II Value Education	2	0	0	0
2ES07	Laboratory 3 (Based on Core) Energy Conversion Laboratory	0	0	4	2
2ES08	Laboratory 4 (Based on Elective) Computer Simulation Laboratory	0	0	4	2
2ES09	Technical Seminar	0	0	4	2
	Total	**14**	**0**	**12**	**18**
Total Credits: 18					

M. Tech., Sem-III

Course Number	Subject	Scheme of Studies Per Week			Credits
		L	T	P	
3ES15	Program Elective V Energy Storage Systems / Smart Grid Technologies Hydrogen and Fuel Cells	3	0	0	3
3ES02	Open Elective Waste to Energy	3	0	0	3
3ES10	Dissertation-I/Industrial Project	0	0	20	10
Total Credits: 16					

M. Tech., Sem-IV

	Subject	Scheme of Studies Per Week			Credits
		L	T	P	
	Dissertation II	0	0	32	16
Total Credits:16					

JNTUH COLLEGE OF ENGINEERING HYDERABAD

M. Tech. I Year I-Sem (Energy Systems) **L T P C**

3 0 0 3

RENEWABLE ENERGY TECHNOLOGIES

Teaching scheme

Lecture: - 3 h/week

Course Code	**1ES01**
Course Name	**RENEWABLE ENERGY TECHNOLOGIES**

Course objectives:

- To explain the concepts of Non-renewable and renewable energy systems
- To outline utilization of renewable energy sources for both domestic and industrial applications
- To analyse the environmental and cost economics of renewable energy sources in comparison with fossil fuels.

LECTURE WITH BREAKUP

Unit1:

Fundamentals of Energy: Energy consumption and standard of living, Oil crisis, Classification of energy resources, Consumption trend of primary energy resources, conventional energy sources and their distribution, Energy chain, common forms of energy, importance and salient features of non-conventional energy resources, environmental aspects of energy, Environment-economy-energy and sustainable development, Energy densities of various fuels, World energy status, Energy scenario in India.

Unit 2:

Solar energy: Solar energy basics, Sun-Earth relation spectrum, Terrestrial and extra-terrestrial radiation, spectral energy distribution of solar radiation, Depletion of solar radiation, measurement of solar radiation, solar radiation data, Solar time, Solar radiation geometry, Solar day length, Empirical equations for estimation of solar radiation on horizontal surfaces, Global, diffused and beam radiation, Solar radiation on inclined surface (Problems on energy availability on surfaces)

Unit 3:

Wind Energy: Wind origin, nature, types, Wind data and wind rose, wind speed variation, Wind siting Wind turbine classification and types of rotors, Wind turbine aerodynamics, power extraction from wind, Betz criteria, Axial thrust on the turbine, torque developed by the turbine, Dynamic matching, speed control strategies, Wind turbine operational characteristics, wind energy conversion systems, environmental aspect, Wind energy potential and installation in India (Problems on energy Conversion)

Unit 4:

Biomass Energy: Biomass resources and their classification**,** Biomass conversion technologies: Thermo chemical conversion - Direct combustion - biomass gasification - pyrolysis and liquefaction - biochemical conversion - anaerobic digestion – operational parameters of biogas plants, Types of biogas Plants and biogas plant design – Alcohol production from biomass - Bio diesel production - Urban waste to energy conversion - Biomass energy program in India (Problems on biogas plant design)

Unit 5:

Ocean Energy: Origin and nature of tidal energy, Tidal range power, tidal energy conversion schemes - Principle of Ocean Thermal Energy Conversion (OTEC) - Ocean thermal power plants- wave energy, power in waves, wave energy technologies- Geothermal power plants - Various types.

Small Hydro Power Plant: Importance of small hydro power plants and their Elements - Types of turbines for small hydro - Estimation of primary and secondary power.

COURSE OUTCOMES	
Student have 1. An understanding of renewable energy sources 2. A knowledge of working principle of various energy systems 3. A capability to carry out basic design of certain renewable energy systems	

Text Books:

1. Renewable Energy Sources, Twidell, J.W. and Weir, A., EFN Spon Ltd., 1986.
2. Renewable Energy Engineering and Technology, Kishore VVN, Teri Press, New Delhi, 2012
3. Renewable Energy Power for a Sustainable Future, Godfrey Boyle, Oxford University Press, U.K, 1996.

Reference Books:

1. Solar Energy - Principles of thermal collection and storage, S. P. Sukhatme
2. Solar Engineering of Thermal Processes, J. A. Duffie and W. A. Beckman
3. Principles of Solar Engineering, Kreith, F and Kreider, J. F., McGraw-Hill, 1978.
4. Renewable Energy, Bent Sorensen, Elsevier, Academic Press, 2011
5. Power Plant Technology, J Wakil
6. Non-Conventional Energy Sources, G.D Rai

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M. Tech. I Year I-Sem (Energy Systems) **L T P C**

3 0 0 3

ENGINEERING HEAT TRANSFER

(Program CORE - II)

Teaching scheme
Lecture: - 3 h/week

Course Code	**1ES02**
Course Name	**ENGINEERING HEAT TRANSFER**

Course objective
• To understand the fundamental laws of Heat transfer modes • To develop the skills to correlate the Physics with applications

LECTURE WITH BREAKUP
Unit 1: **Conduction:** Introduction – Modes of heat transfer – Basic Equations - Combined modes – Steady one-dimensional – Steady heat source system – Conduction Shape Factor - Unsteady heat conduction - Lumped heat capacity system - Infinite solid flat plate - cylinder (Heisler charts). **Types of fins** – Analysis of fins of uniform cross section, effectiveness - Efficiency of fin. Applications**.**
Unit 2: **Forced Convection:** Flow over a flat plate – Analogy between fluid flow and heat transfer - Flow with heat transfer on a Flat Plate – Hydrodynamic and thermal Boundary layer - Laminar and Turbulent Flow - Forced convection over a flat plate – External Flow over other geometries – Internal Flow in a tube - Empirical relations – Numerical Heat transfer. **Free convection** - Free convection from vertical and horizontal surfaces - Enclosed spaces. Applications to flat plate Collectors.
Unit 3: **Radiation:** Overview of Mechanism – laws of radiation- Radiant heat exchange in gray - non-gray bodies – Furnaces – Performance terms and definitions – Furnace heat balance method – Factors affecting furnace performance
Unit 4: **Boiling Heat Transfer:** Regimes of pool boiling – Correlations – Boilers – Performance terms and definitions – Reference standards – Direct Method of Testing – Boiler Efficiency Calculation. **Condensation**: Types – Nusselt's theory of laminar film condensation - Film condensation on horizontal and vertical surfaces - Condensers.
Unit 5: **Heat Exchanger:** Definition and classification – Heat Exchanger Types by flow design, construction, and application - Concept of LMTD and overall heat transfer coefficient - Fouling factor- Derivation of LMTD and effectiveness for parallel and counter flow heat exchangers - NTU approach and design procedure. Purpose of the Performance Test - Performance terms and definitions – Industrial Heat Exchangers - Methodology of heat exchanger performance assessment.

COURSE OUTCOMES	
Student will be able 1. To use the concepts of Heat Transfer and fluid flow in the field of energy applications	

Text Books:

1. Engineering Heat transfer, Cengel and Ghajar, Tata McGraw Hill
2. Engineering Heat Transfer - A basic approach, Necati Ozisik, Mc Graw Hill

Reference Books:

1. Fundamentals of Heat and Mass transfer, Incropera and Dewit, Wiley
2. Heat Transfer, Ghoshdastidar, Oxford University Press
3. Convective Heat Transfer Analysis, Patrick H.Oosthuizen, David Naylor, Mc Graw Hill
4. Engineering heat and mass transfer, Mahesh M Rathore, Laxmi Publications
5. Energy Efficiency In Thermal Utilities (Book 2)
6. Energy Performance Assessment For Equipment And Utility Systems (Book 4)

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M.Tech. I Year I-Sem (Energy Systems)

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3	0	0	3

THERMAL AND NUCLEAR POWER PLANTS

(Program Elective - I)

Teaching scheme
Lecture: - 3 h/week

Course Code	**1ES11**
Course Name	**THERMAL AND NUCLEAR POWER PLANTS**

Course objective
• To obtain knowledge on power generation techniques • To suggest suitable methods to improve the performance of thermal power plants

LECTURE WITH BREAKUP
Unit1: **Introduction to Energy resources**: Types of Resource – Resource availability - Types of power plants - Selection of the power plants – Working of modern thermal power plants - Site selection, coal storage, preparation, coal handling systems, feeding and burning of pulverized fuel, ash handling systems, dust collection-mechanical dust collector and electrostatic precipitator - Review of basic thermodynamic cycles used in power plants.
Unit 2: **Steam Generators and accessories:** Steam generators - Classification – Types – Fluidized bed combustion boilers -High-pressure boilers – Super critical boilers – Steam piping Accessories. Super heaters – Re-heaters – Economizers – Air Preheaters - Pumps and Fans - Types of Condensers – Direct contact condensers - Surface condensers - Feed water heaters – Types – Boiler Makeup – Evaporators - Condensate circulation system – Cooling towers – Types – Wet and dry cooling towers. **Steam Turbines**: Classification – Steam Compounding - Advantages and disadvantages – Governing – Turbine losses – Turbine efficiencies – Turbine materials.
Unit 3: **Gas turbines:** Open and Closed Cycle gas turbines – Design for high temperature - Combined cycles with heat recovery boiler – Combined cycle for power plant – Combined cycle with multi pressure steam - Influence of component efficiencies on cycle performance – IGCC plant. **Combined Cycles:** Constant pressure gas turbine power plants, Arrangements of combined plants (steam& gas turbine power plants), re- powering systems with gas production from coal, using PFBC systems, with organic fluids, parameters affecting thermodynamic efficiency of combined cycles.
Unit 4: **Nuclear Power Plants**: Principles of nuclear energy, basic nuclear reactions,nuclear reactors PWR, BWR, CANDU, Sodium graphite, fast breeder, homogeneous; gas cooled. Advantages and limitations, nuclear power station, waste disposal. **Environmental Aspects:** Environmental aspects of thermal power plants - Constituents of the atmosphere – Power plant pollutants - Oxides of Sulfur, Nitrogen and Carbon – Greenhouse effect – Acid precipitation – Particulate matter – Electrostatic precipitators – Thermal pollution.

Unit 5:
Power Plant Performance: General layout of modern thermal power plants – Components / Equipment in thermal power plant – Coal Mills – Boiler – Draft system – Water pumping system – LP and HP heaters – Turbine – Condenser -– Performance terms and definitions - Performance Evaluation.
Power Plant Economics: load curve, different terms and definitions, cost of electrical energy, tariffs methods of electrical energy, performance & operating characteristics of power plants- incremental rate theory, input-output curves, efficiency, heat rate, economic load sharing, Problems.

COURSE OUTCOMES	
Students will be able to get 1. Exposure to different cycles and their working principle related to thermal power plants	

Text Books:

1. Power Plant Engineering, P.K.Nag / Tata McGraw Hill.
2. Power Plant Technology, El Wakil/ Mc Graw Hill.
3. Energy Efficiency In Thermal Utilities (Book 2)
4. Energy Performance Assessment For Equipment And Utility Systems (Book 4)

Reference Books:

1. A course in Power Plant Engineering, Arora and Domkundwar, Dhanpat Rai.
2. Power Plant Technology, El Wakil/ Mc Graw Hill.
3. Power Plant Engineering, G.R. Nagpal/Khanna Publishers.
4. Power Plant Technology, Rajput.

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M.Tech. I Year I-Sem (Energy Systems)

L	T	P	C
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ENERGY EFFICIENT BUILDINGS

(Program Elective - I)

Teaching scheme

Lecture: - 3 h/week

Course Code	**1ES11**
Course Name	**ENERGY EFFICIENT BUILDINGS**

Course objective

- The course provides knowledge regarding building physics, ventilation technology and indoor climate, etc. that provide a better understanding of building-related problems of various kinds, in order to apply technologies that will contribute to both energy efficient and healthy buildings.

LECTURE WITH BREAKUP

Unit1:

Introduction to energy efficiency in buildings-Architecture- Building Science and its significance- Indoor Environment. Components of Indoor Environment - Classification of building materials based on energy intensity-Energy Management of Buildings and Energy Audit of Buildings.

Unit 2:

Quality of Indoor Environment. Human Comfort-Thermal, Visual, Acoustical and Olfactory comfort. Concept of Sol- air temperature and its significance. Building technology and building services engineering (HVAC) Contribution to lower energy consumption, with different conditions for new and existing buildings.

Unit 3:

Ventilation and is significance. Cooling and heating concepts, Passive solar heating, active solar heating and solar electricity - Passive concepts appropriate for the various climatic zones in India- Electric efficiency for fans, pumps, lighting etc. Heat pumps. Heat exchangers. Experiences from existing energy efficient buildings.

Building related problems and health issues. Indoor climate issues regarding air quality, thermal indoor climate and acoustics. The importance of ventilation for energy efficiency and indoor climate. Building technology and calculations regarding moisture problems.

Unit 4:

Energy management matrix monitoring and targeting. Energy Efficient Landscape Design - Modification of microclimate through landscape elements for energy conservation.

Unit 5:

Case studies: Calculations of the energy balance of buildings without available energy calculation programs, primarily monthly calculations for residential buildings. Energy efficiency and conservation requirements for existing buildings – contradictions and opportunities. Energy efficiency and healthy buildings – contradictions and opportunities – Softwares.

COURSE OUTCOMES	
Students will be able to get 1. Demonstrate a good ability to calculate the energy balance of buildings without the help of available energy calculation programs 2. Assess whether there is a potential conflict between energy conservation and indoor climate for different energy saving measures 3. Analyze and interpret results both critically and independently regarding energy and indoor climate in buildings based on values from both calculations and measurements 4. Demonstrate a good ability to work independently on investigating energy and indoor climate issues for buildings and to present the results both orally and in writing in well-prepared technical reports.	

Text Books:

1. Sodha M.,Bansal N.K., Bansal,P.K Kumar, A. and Malik, M.A.S.,"SolarPassive Buildings", Pergamon Press, 1986.

2. Koenigsberger, O.H., Ingersoll, T.G., Mayhew Alan and Szokolay, S. V., "Manual of Tropical Housing and Building part 1: Climatic Design", OLBN 0 002120011,OrientLongman Limited, 1973.

3. Energy Efficiency In Thermal Utilities (Book 2)
4. Energy Performance Assessment For Equipment And Utility Systems (Book 4)

Reference Books:

1. Levenspiel, *Octave*. Understanding Engineering Thermo. Upper Saddle River, NJ: Prentice Hall, 1996. ISBN: 9780135312032.

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M.Tech. I Year I-Sem (Energy Systems) **L T P C**

3 0 0 3

WASTE MANAGEMENT AND RECYCLING

(Program Elective – I)

Teaching scheme

Lecture: - 3 h/week

Course Code	**1ES11**
Course Name	**WASTE MANAGEMENT AND RECYCLING**

Course objective
• To make the students realize the importance of treatment • To get an exposure to disposal and energy recovery of waste from various industries including agriculture through the knowledge of processes, • To know about Equipment and Materials used in industrial waste – Characteristics & Composition of industrial waste and the pollution control techniques.

LECTURE WITH BREAKUP
Unit1: **Integrated Solid Waste Management:** Solid waste in history – Economics and solid waste – Legislation and regulation – Materials flow – Reduction – Reuse – Recycling – Recovery – Disposal of solid waste in landfills – Energy conversion – The need for integrated solid waste management – Special wastes – E-waste materials and its recovery.
Unit 2: **Landfills:** Planning, siting and permitting of landfills – Planning – Siting – Permitting – Landfill processes – Biological degradation – Leachate production – Gas production – Landfill design – Liners – Leachate collection – Treatment and disposal – Landfill gas collection and use – Geotechnical aspects of landfill design – Storm water management – Landfill cap – Landfill operation – Landfill equipment – Filling sequences – Daily cover – Monitoring – Post closure care and use of old landfills – Landfill mining.
Unit 3: **Process Effluents:** Manufacturing process and sources of effluent from the process of industries like chemical – Fertilizer – Petroleum – Petrochemical –Paper –Sugar – Distillery – Textile – Tannery – Food processing – Dairy and steel manufacturing – Characteristics and composition of effluent and different methods of treatment & disposal of effluent for the following industries steel – Petroleum refineries – Textiles – Tanneries - Atomic energy plants and other mineral processing industries.
Unit 4: **Waste Water Treatment Methods:** Nitrification and de-nitrification – Phosphorous removal – Heavy metal removal – Membrane separation process – Air stripping and absorption processes – Special treatment methods – Disposal of treated waste.
Unit 5: **Environmental Issues in Agriculture:** Types of farming systems – Agro meteorology – Water and nutrients requirement – Fertilizers – Types of fertilizers – Pesticides and other agrochemicals – Solid and water conservation practices.

COURSE OUTCOMES	
Students shall be able 1. To Categorize the waste from various industries & recycle for energy extraction.	

Text Books:

1. Industrial Solid Waste Management and Landfilling practice, M. Dutta, B.P. Parida, B.K. Guha and T. R. Surkrishnan. Narosa Publishing House, New Delhi (1999).
2. Environmental Pollution
3. Control Engineering, C.S.Rao Wiley Eastern Ltd. New Delhi (1995).

Reference Books:

1. Industrial Waste Water Pollution Control, W. Wesley Eckenfelder Jr., McGraw Hill,2000.
2. Wastewater Treatment for Pollution Control, McGraw- Hill, Arceivala, S.J.,1998. M. N. Rao & Datta, Waste Water Treatment, 3rd Edition, Oxford & IBH publishing Company Pvt Ltd.
3. Treatment of Industrial Effluent, Callegy, Forster and Stafferd, Hodder and Stonghton, 1988.
4. Hand book of solid waste management and Waste Minimization Technologies Nicholas P. Chermission off. An imprint of Elsevier, New Delhi (2003).
5. Solid Waste Engineering, P. Aarne Vesilind, William A. Worrell and Debra R. Reinhart. Thomason Asia Pte Ltd. Singapore (2002).
6. Design, Construction and Monitoring of Landfills, Amalendu Bagchi,.John Wiley and Sons..,New York. (1994).

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M.Tech. I Year I-Sem (Energy Systems) **L T P C**

3 0 0 3

MEASUREMENT SYSTEMS IN ENERGY ENGINEERING

(Program Elective - II)

Teaching scheme

Lecture: - 3 h/week

Course Code	**1ES12**
Course Name	**MEASUREMENT SYSTEMS IN ENERGY ENGINEERING**

Course objectives:

- To study the characteristics of instruments.
- To analyse various types of transducers based on the principle of operation and construction.
- To understand about various measuring devices and their calibration.

LECTURE WITH BREAKUP

Unit1:

Basic concepts: Calibration – Standards- Dynamic measurement- System response.

Elements of a Measurement System: Basic Instrumentation system – Classification of instruments - Errors and Uncertainties in measurement.

Electrical transducers: Resistive Transducers - Inductive Transducers – Capacitive transducers - Thermoelectric Transducers and Photoelectric Transducers - Piezoelectric Transducers.

Unit 2:

Basic Signal Conditioning Elements: Amplifiers- Non-Electrical and Electrical types - Op Amps-Summing, Differential, and Charge Amplifiers - Differentiating and Integrating Elements – Filters – A to D and D to A Converters - Data Transmission Elements- Electrical, Pneumatic, Position and Radio Frequency Transmission types.

Velocity Measurement: Contact type - AC-DC Tachometers Non-contact type - Magnetic, Photoelectric & stroboscopic methods. Flow measurement and Flow meters-Visualization methods.

Unit 3:

Acceleration measurement: Seismic Accelerometer & Piezoelectric Accelerometer.

Solar radiation: Pyranometer, Pyrheliometer, sunshine recorder

Measurement of Radiation: Radiation Fundamentals - Radiation detectors - Optical pyrometer.

Measurements of thermal-and-transport-property: viscosity, thermal conductivity, diffusion coefficient, pH, humidity, heat transfer coefficient, heat flux, etc. Thermal Imaging.

Unit 4:

Mechanical Transducers:

Measurement of Temperature: Bimetallic Element and Fluid Expansion type Thermometers.

Measurement of Pressure: Manometers and Bourdon Gauges - Load Cells and Elastic Force Devices.

Measurement of Force: Different methods - Strain gauge load cell method.

Measurement of torque: Strain gauge method.

Data analysis: Error analysis, Uncertainty analysis, Statistical analysis, Graphical analysis and curve fitting, Multivariable regression, Goodness of fit.

Unit 5:

Feedback in Instruments: Principles of Feedback - Advantages & Disadvantages of Feedback

Digital Voltmeters: Ramp and Dual Slope types – Servo type Potentiometric and Magnetic tape Recorders – Digital Recorders of Memory type-Data displays: Analog and Digital types.

COURSE OUTCOMES	
Student will be able to 1. Select the transducer and their types, usage and operation and different characteristics of transducers. 2. Calibrate the various instruments and apply to different instruments in the field.	

Text Books:

1. Modern Electronic Instrumentation and Measurement Techniques; Albert D Helfrick and William D Cooper; 2004, PHI.

Reference Books:

1. Instrumentation, Measurement and Analysis; BC Nakra, and KK Chaudhry, 2 ed, 2004, Tata McGraw-Hill
2. Transducers and Instrumentation; DVS Murthy, 2003, PHI
3. Instrumentation Devices and Systems, CS Rangan, GR Sarma, and VSV Mani, 2nd Ed, Tata McGraw-Hill
4. Measurement Systems Application and Design; Doeblin and Ernest; 5th Ed, 2004, Tata McGraw-Hill.
5. Measurement Systems – Applications & design, Doeblin E.O. 4th Ed. Mc. Graw Hill
6. Principles of Industrial Instrumentation, Patranabis D. ,Tata McGraw Hill – 1997.
7. Mechanical & Industrial Measurements, Jain R.K, Khanna Publishers – 1986.

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M. Tech. I Year I-Sem (Energy Systems)

L	T	P	C
3	0	0	3

APPLIED THERMODYNAMICS

(Program Elective - II)

Teaching scheme
Lecture: - 3 h/week

Course Code	**1ES12**
Course Name	**APPLIED THERMODYNAMICS**

Course objective:

- To predict the condition of systems and analyze them by the criteria of equilibrium.
- To apply the concepts of advanced thermodynamics to combustion systems and refrigeration systems.

LECTURE WITH BREAKUP

Unit 1:

Introduction: Thermodynamic system - types – properties – Zeroth Law of Thermodynamics – Measurement of Temperature - Work Transfer and Heat Transfer – First Law of Thermodynamics applied to Closed and Open Systems - Second Law of thermodynamics – Concept of entropy – Clausius inequality – Available energy - Availability – Irreversibility.

Unit 2:

Properties of Perfect Gases: Laws of Perfect gases – Boyle's Law – Charles Law – Gay Lussac Law – General gas equation – Joule's law – Characteristic equation of gas – Avagadro's law – Universal gas constant – Specific heat of a gas – Specific heat and constant volume and pressure – Enthalpy of a gas – Relation between specific heats.

Unit 3:

Gas Power Cycles: Carnot cycle - Air standard assumptions - Otto cycle - Diesel cycle – Dual cycle – Stirling cycle – Ericsson cycle – Brayton cycle – Brayton cycle with Inter cooling, Reheating and Regeneration.

Unit 4:

Vapor Power Cycles (Elementary treatment only): Carnot vapor cycle – Ideal Rankine cycle – Deviation of Actual Vapor power cycle from Ideal cycle – Actual Rankine cycle – Methods to increase efficiency of Rankine cycle (Lowering of condenser pressure - Super heating steam to High temperature - Increasing Boiler pressure) – Reheat and Regenerative Rankine cycle.

Unit 5:

Psychometry & Air Conditioning: Dry and atmospheric air – Specific and relative humidity of air – Dew point temperature – Adiabatic saturation and wet bulb temperature – The psychometric chart – Human comfort and air conditioning.

Refrigeration cycles: Applications – air refrigeration – vapour compression refrigeration – effects of operating parameters – COP – vapour absorption refrigeration system.

Converters and Energy Storage Devices: Fundamentals of convertors - Thermo-electric- MHD - basics of energy storage devices – Thermo-chemical energy storage – Sensible and Latent heat storage – Chemical Energy Storage – Electromagnetic energy storage - Working – governing - parameters.

COURSE OUTCOMES	
Students will 1. Analyze the engineering systems to improve and optimize its performance 2. Understand the working and the design principles of combustion systems and refrigeration systems.	

Text Book:

1. Thermodynamics – An Engineering Approach , Y.A.Cengel and Mc. A. Boles.
2. Basic and Applied Thermodynamics, P.K.Nag, Tata Mcgraw Hill

Reference Books:

1. Thermodynamics / Sontag & Van Wylen
2. Thermodynamics / YVC RAO.
3. Introduction to the Thermodynamics of Materials – David R. Gaskell

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M.Tech. I Year I-Sem (Energy Systems) **L T P C**

3 0 0 3

ENVIRONMENTAL POLLUTION AND CONTROL

(Program Elective - II)

Teaching scheme
Lecture: - 3 h/week

Course Code	**1ES12**
Course Name	**ENVIRONMENTAL POLLUTION AND CONTROL**

Course objective:
• To understand the concepts of pollution/pollutants and its impact on the environment.

LECTURE WITH BREAKUP
Unit 1: **Overview of Environmental Concepts:** Global Warming - Ozone Layer & UV Radiations - Deforestation - Energy & Matter Cycles - Case Studies of Significant Environmental Problems and Disasters and the lessons learnt. Influence of pollution regionally and globally.
Unit 2: **Air Pollution:** Natural and anthropogenic sources of pollution - Primary and Secondary pollutants - Transport and diffusion of pollutants - Gas laws governing the behavior of pollutants in the atmosphere - air sampling methods.
UNIT 3: **Air Pollution Control:** Methods of monitoring and control of air pollutants $S0_2$ NO_2, CO, SPM - Effect of pollutants on human beings – Plants – Animals - Materials and on climate - Acid Rain - Ambient Air Quality Standards - Air pollution control methods and equipment.
Unit 4: **Solid Waste:** Sources and classification of land pollutants - Industrial waste effluents and heavy metals - Their interactions with soil components - Degradation of different insecticides - Fungicides and weedicides in soil - Solid waste management - Process and equipment for energy recovery from municipal solid waste and industrial waste - MSW Act 2000.
Unit 5: **Water Pollution:** Types - Sources and consequences of water pollution – Physical - chemical and Bacteriological sampling and analysis of water quality – Standards - Sewage and waste water treatment and recycling ASP/STP - Water quality standard – Treatment - Utilization and disposal of sludge - Government norms.

COURSE OUTCOMES	
Student will be able to 1. Have knowledge of continual degradation of environment due to pollutants. 2. Have an exposure to different types of pollution control methods.	

Text Book:

1. Environmental Pollution Control Engineering, C. S. Rao, Wiley Eastern Ltd., Delhi 1991.

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, Mc Graw Hill.
4. Energy & Environment, J.M. Fowler, Mc Graw Hill.

JNTUH COLLEGE OF ENGINEERING HYDERABAD

M.Tech. I Year I-Sem (Energy Systems)

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2	0	0	2

RESEARCH METHODOLOGY AND IPR

Teaching scheme
Lecture: - 3 h/week

Course Code	**1A111**
Course Name	**RESEARCH METHODOLOGY AND IPR**

Course objectives:

- To understand the research problem
- To know the literature studies, plagiarism and ethics
- To get the knowledge about technical writing
- To analyze the nature of intellectual property rights and new developments
- To know the patent rights

LECTURE WITH BREAKUP

UNIT-I:

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

Unit 2:

Effective literature studies approaches, analysis Plagiarism, Research ethics.

Unit 3:

Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee.

Unit 4:

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Unit 5:

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications. New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs

COURSE OUTCOMES

Students will be able to

1. Understand research problem formulation.
2. Analyze research related information
3. Follow research ethics
4. Understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity.

5. Understanding that when IPR would take such important place in growth of individuals & nation, it is needless to emphasis the need of information about Model Curriculum of Engineering & Technology PG Courses [Volume-I] [16] Intellectual Property Right to be promoted among students in general & engineering in particular.
6. Understand that IPR protection provides an incentive to inventors for further research work and investment in R & D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits.

TEXT BOOKS:

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'"
2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"

Reference Books:

1. Ranjit Kumar, 2nd Edition , "Research Methodology: A Step by Step Guide for beginners"
2. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
3. Mayall , "Industrial Design", McGraw Hill, 1992.
4. Niebel , "Product Design", McGraw Hill, 1974.
5. Asimov , "Introduction to Design", Prentice Hall, 1962.
6. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
7. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

JNTUH COLLEGE OF ENGINEERING HYDERABAD

M.Tech. I Year I-Sem (Energy Systems)

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ENGLISH FOR RESEARCH PAPER WRITING
(Audit Course)

Teaching scheme
Lecture: - 3 h/week

Course Code	**1A112**
Course Name	**ENGLISH FOR RESEARCH PAPER WRITING**

Course objective
Students will be able to: • Understand that how to improve your writing skills and level of readability • Learn about what to write in each section • Understand the skills needed when writing a title • Ensure the good quality of paper at very first-time submission

LECTURE WITH BREAKUP
Unit 1: Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness.
Unit 2: Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticising, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts, Introduction
Unit 3: Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check.
Unit 4: Key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature.
Unit 5: Skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions

Text Books:-

1. Writing for Science, Goldbort R (2006), Yale University Press (available on Google Books)
2. How to Write and Publish a Scientific Paper, Day R (2006), Cambridge University Press.
3. Handbook of Writing for the Mathematical Sciences, Highman N (1998), Highman's book. SIAM.
4. English for Writing Research Papers, Adrian Wallwork , Springer New York Dordrecht Heidelberg London, 2011.

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RENEWABLE ENERGY LABORATORY

Teaching scheme
Lecture: - 3 h/week

Course Code	**1ES03**
Course Name	**RENEWABLE ENERGY LABORATORY**

Course objective:
• To determine the efficiency of various renewable energy systems.

LECTURE WITH BREAKUP
Study of 1. Operational experience on i) Pyranometer, ii) Sunshine recorder. 2. Measurement of speed using Tachometer, Stroboscope and anemometers.
List of experiments 1. Performance evaluation of a solar Flat Plate Thermosyphon water heating system. 2. Conversion efficiency of a solar Flat Plate Forced Circulation water heating system. 3. Conversion efficiency of a solar Evacuated Tube water heating system. 4. Determination of conversion efficiency of a solar Air Heating system. 5. Performance estimation of photovoltaic water pumping system. 6. Estimation of moisture removal from a solar dryer. 7. Determination of characteristics of a wind generator. 8. Performance evaluation of solar cooker. 9. Performance evaluation of horizontal axes wind turbine. 10. Study and analysis of a solar still / distillation plant.

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ENERGY COMPUTATIONAL LABORATORY

Teaching scheme
Lecture: - 3 h/week

Course Code	**1ES04**
Course Name	**ENERGY COMPUTATIONAL LABORATORY**

Course objective

1. To expose to programming language, C / Fortran
2. To solve problems in renewable energy conversion technologies, Heat transfer and fluid flow

1. Fundamentals of C Programming
2. Applications of C programming in the following areas:
   i) Problems related to Renewable Energy Sources such as Solar and Wind
   ii) Problems related to Heat transfer
   iii) Problems related to Measurements and Control Systems

1. Programming using high level language (C/C++/Fortran/MATLAB) (8)
2. Computer programming for solving linear simultaneous equations, non-linear equations.(8)
3. Numerical differentiation and integration.(8)
4. Solution of ordinary differential equations and solution of partial differential equations.(8)
5. Eigen value problems, Boundary value, Initial value problems.(4)
6. Problems as assigned by the respective teachers.(4)

COURSE OUTCOMES	

Student get

1. Exposure to C programming
2. Expertise in developing programs in various applications.

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DIRECT ENERGY CONVERSION

(Program Core - III)

Teaching scheme
Lecture: - 3 h/week

Course Code	**2ES05**
Course Name	**DIRECT ENERGY CONVERSION**

Course objective:
To analyze the working principle, pros and cons of • Conventional energy conversion techniques • Direct energy conversion systems • Need and necessity of integration of different energy systems with grid.

LECTURE WITH BREAKUP
Unit1: **Photovoltaic Fundamentals:** Place of PV in energy supply – PV Cells, Modules and arrays, & costs, Review of semiconductor physics and Operating principle-–Introduction to P-N and P-I-N junctions - Equilibrium and non-equilibrium conditions-Design of solar cells: Cell parameters limits-Losses in solar cells-Solar cell design for high I_{sc}, V_{oc} and FF.
Unit 2: **Solar cell technologies:** Silicon based technologies (mono-crystalline, poly-crystalline, ribbon, silicon film), Flow of silicon material, Manufacturing processes (wafer, cell and module) for Mono and poly Si technologies, Efficiency of Si cells; Thin film technologies (Silicon and Non-silicon): Material-deposition techniques, Amorphous Si cells/modules, micro-morph cell, Silicon film- Non-silicon technologies viz Cadmium telluride, Cu Indium Gallium Diselenide. Concept of multi-junction or tandem cells, concentrating technologies-Optics for concentrators - PV-Tracking requirements-High concentrator solar cells. Emerging solar cell technologies : Mono PERC (Passivated Emitter Rear Cell), Topcon (Tunnel Oxide Passivated Contact), n-type solar cells, HJT-Heterojunction Technology, Perovskite Solar Cells (Single junction and tandem), Quantum dots, Dye Sensitized Solar cell etc.
Unit 3: **PV module and PV System applications:** Solar PV modules-Mismatch in series and parallel connection-design & structure of PV modules-PV module power output-Batteries for PV systems-DC to DC and DC to AC converters-charge controllers-MPPT; Standalone PV systems-Design methodology of PV off grid and grid connected systems- Load estimation and System Sizing, Wire sizing in PV systems-Grid connected and hybrid PV systems. Design of roof top solar PV power plants (typically 100 kWp), Flowchart for the design of solar PV power plants-Solar PV Water pumping systems, Agrivoltaics (concept and potential), Floating solar PV Systems. **Energy Storage Devices:** Different types of Batteries, working, performance governing parameters, hydrogen energy.
Unit 4: **Hydrogen Fuel and Fuel Cells :** Introduction to Hydrogen usage in IC engines – Hydrogen Induction

and injection in IC engines – Exhaust Gas Recirculation mechanism to minimise NOX emissions from Hydrogen engine-Principle of fuel cell operation and different types of fuel-cells reactions, electrochemical thermodynamics, Relation of cell potential to thermodynamic variables, Cell efficiency, Polarization losses, Types of fuel cells, Performance characteristics, Applications.

Thermo electric: Thermoelectric Power Generation: Introduction, Thermoelectric effects, Thermodynamic analysis of thermoelectric generator, Maximum thermal efficiency and maximum power output, Single stage and multistage generators, thermoelectric materials, Applications.

Unit 5:

Integration of renewable energy sources: Overview of challenges in integrating renewable sources to the grid - Need to maintain voltage within a band and fluctuations in voltage because of renewable integration - Power inverter and converter technologies - Mechanism to synchronize power from renewable sources to the grid - Overview of challenges faced in designing power injection from offshore generation sources- Hybrid systems - Thermal/PV hybrid system-Solar/wind hybrid system – Floating solar PV panels.

COURSE OUTCOMES	
Students get 1. Awareness on the existence of various mechanisms for conversion of energy, 2. Exposure to merits, constraints and drawbacks	

Text Books:

1. Energy Conversion, Mechanical Engineering Handbook, "D. Yogi Goswami"
2. Solar Energy - Principles of thermal collection and storage, S. P. Sukhatme
3. Solar Photovoltaics: Fundamentals, Technologies and Applications by Chetan Singh Solanki , Prentice Hall of India, 2011 updated
4. Solar Photovoltaic Technology and Systems; A manual for Technicians, Trainers and Engineers by Chetan Singh Solanki, PHI , 2013

Reference Books:

1. "Energy Conversion", Lawrence Conway, Westinghouse Electric Corporation "Microgrids and Active Distribution Networks", S. Chowdhury, S.P. Chowdhury, P. Crossley, Institution of Engineering and Technology, 30 Jun 2009.
2. https://www.nrel.gov/
3. http://mnre.gov.in/

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ENERGY CONSERVATION IN THERMAL SYSTEMS

(Program Core - IV)

Teaching scheme
Lecture: - 3 h/week

Course Code	**2ES06**
Course Name	**ENERGY CONSERVATION IN THERMAL SYSTEMS**

Course objective:

- To understand the concepts of energy conversion in thermal utilities and estimate the performance.

LECTURE WITH BREAKUP

Unit1:

Energy Management: Energy Scenario - Energy needs of Growing Economy – Energy Security – Energy Conservation and its importance – Energy strategy for future energy needs - Energy Conservation Act, 2001 and its features - Responsibilities and duties of Energy Manager as per Act - Activities in Energy Management (Formation of Energy Team, Institute Energy Policy, Data Collection and management, Establishing Baseline, Benchmark, Analysis and Evaluation, Conduct of Technical Assessment, Estimate potential for improvement, Establish Goals)- Role of energy manager.

Energy Audit: Objectives of Energy Management – Energy Audit Types – Audit Methodology – Steps in Energy Audit – Energy Costs – Benchmarking and Energy Performance – Matching energy Usage to Requirement – Maximizing System Efficiency – Energy index – Cost index - Energy Audit Instruments.

Unit 2:

Fuels and Combustion: Properties of Solid, liquid, and gaseous fuels – Fundamentals of combustion - Combustion analysis – Draft – Combustion control. (Problems on combustion air requirements)

Boilers – Types - FBC Boilers - Mechanism of Fluidized Bed – Advantages – Types of FBC Boilers – Operational Features –Advantages and disadvantages – Applications – Saving Potential –Boiler Performance Evaluation – Direct method - Indirect Method - Boiler water Treatment – Energy Conservation Opportunities. (Estimation of energy losses and efficiency).

Unit 3:

Furnaces: Classification – Performance Evaluation – Indirect Method of Evaluation - Fuel Economy Measures (Air Preheater – Heat losses and Prevention).(Estimation of energy losses and efficiency)

Pumps and Pumping System: Classification of Pumps – System Characteristics – Factors affecting pump performance – Efficient pumping system operation – Flow Control strategies – Pumps in series and in parallel – Energy Conservation Opportunities. (Problems on series and parallel flow in pumps and friction estimation)

Insulation and Refractories: Insulation– Types and Applications – Economic Thickness of Insulation – Optimum selection of pipe size - Heat Savings and Application Criteria – Refractories – Selection of Refractories

Unit 4:

Energy Conservation: List of Energy Intensive Industries - Sankey diagram – Material and Energy

balance – Energy Conservation - Rules for Efficient Conservation of Materials and Energy - Identification of Energy Conservation opportunities - Technologies or Approach for Energy Conservation – Energy Conservation Schemes and Measures - Energy flow networks - Critical assessment of energy use - Optimizing Energy Inputs and Energy Balance - Pinch Technology – Energy Conservation in compressed air, Cooling Tower and Refrigeration systems.

Unit 5:

Waste Heat Recovery Systems: General Classification – Benefits of Waste heat Recovery – Waste Heat Recovery Devices (Recuperator, Regenerators, Heat Wheels, Heat Pipe, Economizers, Heat Pump).

Cogeneration: Definition – Basic Thermodynamic Cycles – Classification of Cogeneration Systems - Advantages. **Global Environmental Concerns**: Climate Change Problem and Response – Conference of Parties – Prototype Carbon Fund.

Financial Management: Investment need, Appraisal and Criteria – Financial analysis – Financial Techniques (Simple Payback period, Return on Investment, Net Present Value, Internal Rate of Return), Cash Flow Diagrams..

COURSE OUTCOMES	
Student will be able to 1. Have knowledge of equipment used in thermal power plants. 2. Estimate the conversion efficiency of the components.	

Text Books:

1. T_5119_Energy_Efficiency_In_Thermal_Utilities Book 2.
2. T_5121_Energy_Performance_Assessment_For_Equipment_And_Utility_Systems_Book 4.

Reference Books:

1. Analysis of Engineering Cycles, R. W. Haywood, 4th Edition, Pergamon Press, Oxford, 1991.
2. Boiler Control Systems, D. Lindsay, Mcgraw Hill International, London, 1992.
3. Least Cost Electrical Utility / Planning, H. G. Stoll, John Wiley & Sons, 1989.
4. Short Term Forecasting: An introduction to the Box Jenkins Approach, T. M. O` Donovan, Wiley, Chichester, 1983.
5. Industrial Energy Management and Utilization, 1988, LC Wittie, P S Schmidt and D R Brown, Hemisphere Publishing Company.

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M.Tech. I Year II-Sem (Energy Systems) **L T P C**

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ENERGY EFFICIENCY IN ELECTRICAL UTILITIES

(Program Elective - III)

Teaching scheme
Lecture: - 3 h/week

Course Code	**2ES13**
Course Name	**ENERGY EFFICIENCY IN ELECTRICAL UTILITIES**

Course objectives:

- To have basic concepts of Electrical systems, motors, lighting systems.
- To apply Electrical systems for Power Factor improvement.
- To illustrate the application of different electrical systems in improving energy efficiency.

LECTURE WITH BREAKUP

Unit1:

Electrical Systems: Electrical Power Supply Systems – Electricity Billing – Load Management and Maximum demand control – Power factor improvement and its benefits – Selection and location of capacitors – Performance assessment of PF capacitors Transformers – System Distribution Losses.

Unit 2:

Analysis of Power Systems: Analysis of System load curve -plant load factor, availability, Loss of load Probability calculations for a power system, Maintenance Scheduling - Pricing of Power - Project cost components, Analysis of Power Purchase Agreements (PPA), Debt/Equity Ratio and effect on Return on Investment, Environmental Legislations/Government Policies - Optimal Dispatch - Scheduling of Hydro-Thermal plants, Load Forecasting - Time series, Econometric, end use techniques. Least Cost Power Planning.

Unit 3:

Electric Motors: Motor Types – Motor Characteristics – Motor Efficiency – Selection of Motors – Energy Efficient Motors – Factors affecting Energy Efficiency – Minimization of Motor Losses in Operation – Rewinding effects on Energy Efficiency – Speed control of AC induction Motors – Motor Load Survey: Methodology.

Compressed air systems: Performance – Advantages and applications – Efficient operation of compressed gas.

Unit 4:

Lighting System: Basic terms in lighting system and their features – Lamp types and their features – Recommended illuminance levels – Methodology of lighting systems – Case studies – Good practices in lighting system.

Fans and Blowers: Performance evaluation – Efficient System Operation – Fan Performance Assessment. Energy Saving Opportunities.

DG Set System: Introduction – Selection and Installation factors – Operational factors – Energy performance assessment of DG sets – Energy Saving measures for DG sets.

Unit 5:

Energy Efficiency Technologies: Maximum demand controllers – Automatic Power factor controllers – Energy efficient motors – Soft starters – Variable speed drives – Performance terms and definitions – Efficiency testing – Determining Motor Loading – Performance evaluation of Rewound motors – Application of Variable Speed Drives - Energy efficient transformers – Electronic ballasts –

Energy efficient lighting controllers.
COURSE OUTCOMES
Student will be able to 1. Understand the concepts of improvement of power factor of an Electrical system and lighting system. 2. Understand the implementation of Energy Efficient Technologies in Electrical Systems.

Textbooks:

1. Energy Efficiency for Engineers and Technologists, Eastop T.D & Croft D.R, Logman Scientific & Technical, ISBN-0-582-03184, 1990.
2. Industrial Energy Conservation, Reay D.A, 1st edition, Pergamon Press, 1977.

Reference Books:

1. Power Plant Engineering, P.K.Nag / Tata McGraw Hill.
2. Power Plant Performance, A. B. Gill, Butterworths, 1984.
3. Power Generation, operation & control, A. J. Wood and B. F. Wollenberg, John Wiley, New York, 1984.
4. Power System Engineering, 2nd Ed. D P Kothari, I J Nagrath, Tata McGraw-Hill Co 2008
5. The Energy and Resource Institute (TERI): http://www.teriin.org/
6. Energy Efficiency for Engineers and Technologists, First Edition, 1990, by TD Eastop and DR Croft, Longman Group UK Ltd.
7. Bureau of Energy Efficiency (BEE): www.beeindia. gov.in/content/energy-auditors.

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M. Tech. I Year II-Sem (Energy Systems) **L T P C**
3 0 0 3

NUCLEAR POWER PLANTS
(Program Elective – III)

Teaching scheme
Lecture: - 3 h/week

Course Code	**2ES13**
Course Name	**NUCLEAR POWER PLANT**

Course objective:
• To understand the concepts of pollution/pollutants and how to protect it from the environment.

LECTURE WITH BREAKUP
Unit 1: **NUCLEAR FUEL AND REACTOR THEORY:** Nuclear fuels-occurrence and extraction, fissile characteristics, enrichment, fission process - thermal and fast fission - energy released from fission - chain reaction - reaction control. Neutron balance - fast fission - resonance capture – thermalization - geometric effects - burn-up – introduction to reactor kinetics.
Unit 2: **REACTOR COMPONENTS:** General components of nuclear reactor - Fuel cladding - fuel assembly – moderators – coolants - control rods - Reactor safety - Neutron Population growth - assurance of safety - emergency core cooling and containment.
Unit 3: **REACTOR TYPES**: Different types of reactors - Pressurized Water Reactor - Boiling Water Reactor - Heavy Water-cooled Reactor -Gas cooled Reactor - Liquid metal cooled reactor - Organic moderated and cooled reactors - Fast Breeder Reactors – Fifth generation reactors.
Unit 4: **RADIOACTIVE WASTE MANAGEMENT:** The nuclear fuel cycle - Waste classification - Spent fuel storage – Transportation – Reprocessing - High-Level waste disposal - low-level waste generation and treatment - Low-level waste disposal - Nuclear power plant decommissioning.
Unit 5: **NUCLEAR POWER FOR PROPULSION AND ENERGY ECONOMICS:** Reactors for naval propulsion - Space reactors - Space isotopic power generator - Energy economics -Components of electrical power – Cost forecast versus Reality - Challenges and opportunities - Technical and institutional improvements – Developments in nuclear reactor.

COURSE OUTCOMES	
Student will be able to 1. Have knowledge of continual degradation of environment. 2. Have an exposure to different types of pollutions control methods.	

Text Book:

1. Principle of Energy Conversion, Archie W.Culp, McGraw Hill, Kogakusha Ltd., 1984.

Reference Books:

1. Nuclear Power Technology, W. Marshall, Vol. I &II, Clarendon press, Oxford, 1985.
2. Principle of Nuclear Reactor Engineering, Samual Glasstone, Van Nostrand Reinhold Co. Inc., New York, 1963.
3. A course in Power Plant Engineering, Arora and Domkundwar, Dhanpat Rai.
4. Power Plant Technology, El Wakil/ Mc Graw Hill.
5. Power Plant Engineering, G.R. Nagpal/Khanna Publishers.
6. Power Plant Technology, Rajput.

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MODERN CONTROL SYSTEMS

Teaching scheme
Lecture: - 3 h/week

Course Code	**2ES13**
Course Name	**MODERN CONTROL SYSTEMS**

Course objective
• To understand the concepts of linear control systems. • To study about controllability and observability and their application to different control systems. • To study about non-linear control systems and also to obtain stability analysis.

LECTURE WITH BREAKUP
UNIT-1 INTRODUCTION: Concepts of Control Systems- Open Loop and closed loop control systems and their differences- Different examples of control systems- Classification of control systems- Feed-Back Characteristics- Effects of feedback. Mathematical models – Differential equations - Impulse Response and transfer functions - Translational and Rotational mechanical systems. **TRANSFER FUNCTION EPRESENTATION:** Transfer Function of DC Servo motor - AC Servo motor- Synchro transmitter and Receiver- Block diagram representation of systems considering electrical systems as examples - Block diagram algebra – Representation by Signal flow graph - Reduction using mason's gain formula.
UNIT-2 TIME RESPONSE ANALYSIS: Standard test signals - Time response of first order systems – Characteristic Equation of Feedback control systems, Transient response of second order systems - Time domain specifications – Steady state response - Steady state errors and error constants – Effects of proportional derivative, proportional integral systems.
UNIT - 3 STABILITY ANALYSIS: The concept of stability - Routh stability criterion – qualitative stability and conditional stability. **Root Locus Technique:** The root locus concept - construction of root loci-effects of adding poles and zeros to G(s) H(s) on the root loci. **Frequency Response Analysis:** Introduction- Frequency domain specifications-Bode diagrams-Determination of Frequency domain specifications and transfer function from the Bode Diagram-Phase margin and Gain margin-Stability Analysis from Bode Plots.
UNIT-4 **STABILITY ANALYSIS IN FREQUENCY DOMAIN:** Polar Plots- Nyquist Plots and applications of Nyquist criterion to find the stability - Effects of adding poles and zeros to G(s)H(s) on the shape of the Nyquist diagrams. **Classical Control Design Techniques:** Compensation techniques – Lag- Lead- and Lead-Lag Controllers design in frequency Domain- PID Controllers
UNIT – 5 **STATE SPACE ANALYSIS OF CONTINUOUS SYSTEMS**: Concepts of state- state variables and state model- derivation of state models from block diagrams, Diagonalization- Solving the Time invariant state Equations- State Transition Matrix and its Properties.

COURSE OUTCOMES	
Students obtain 1. knowledge on control techniques which are applicable to all phases of life including energy systems 2. An exposure to both linear and non-linear advanced control techniques	

Text Books:

1. Control Systems Engineering, I.J. Nagarath and M.Gopal, New Age International (P) Ltd.
2. Modern Control Engineering, K. Ogata, Prentice Hall of India, *3rd* edition, 1998

Reference Books:

1. Automatic Control Systems, Benjamin C. Kuo, John Wiley, 2009
2. Control systems, N.K. Sinha, New Age International Publishers, 3rd edition
3. Modern Control System Theory, M. Gopal, New Age International Publishers, 2nd edition, 1996
4. Modern control System, Dorf, Pearson.

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OPTIMIZATION OF ENERGY SYSTEMS
(Program Elective – IV)

Teaching scheme
Lecture: - 3 h/week

Course Code	**2ES14**
Course Name	**OPTIMIZATION OF ENERGY SYSTEMS**

Course objective:

- To have a knowledge of optimization of design parameters.
- To have an exposure to different design methodologies and simulation processes.

LECTURE WITH BREAKUP

Unit1:

Thermal Systems – Characteristics- formulation of design problem - Steps in the design process - Modeling of thermal systems – importance - Types of models - Mathematical Modeling

Unit 2:

Linear programming models – Formulation - Simplex method – Artificial variable technique – Big M method - Concept of Sensitive analysis.

Unit 3:

Unconstrained Optimization: Single variable optimization – Fibonacci & Golden section method - Multi variable optimization – Gradient methods – Gradient of the function - Steepest descent – Flecher-Reeves method -Variable metric method - Constrained Non-linear Optimization Methods - Lagrangian multiplier – Application to thermal and electrical systems.

Unit 4:

Geometric programming – Polynomial – Arithmetic and Geometric inequalities – Unconstrained GP - Constrained GP with constraints of type less than or equal- Application to thermal and electrical systems- Dynamic Programming- Bellman's principle of optimality- Shortest route problems

Unit 5:

Simulation - Definition- Types of Simulation models - Steps involved in simulation models - Application of simulation - Advantages and disadvantages – Introduction to Genetic algorithm – Applications in Genetic Algorithm - Similarities and dissimilarities with traditional methods - Genetic operators.

COURSE OUTCOMES

Students have an exposure to

1. Numerical calculations
2. Role of design parameters
3. Simulation models like genetic algorithms

Text Books:

1. Design and Optimization of Thermal Systems, Yogesh Jaluria, McGraw Hill.
2. Optimization theory and applications, S.S.Rao, New Age Publication.

Reference Books:

1. Design of Thermal System, W.F.Stoecker, McGraw Hill.
2. Operation Research, Panner Selvam, Prentice Hall.
3. Optimization Research, M.C.Joshi.
4. Simulation Modeling & Analysis, Law & Kelto.
5. Operation Research, S Prinsc Valle Kasur.

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WIND ENERGY CONVERSION SYSTEMS
(Program Elective-IV)

Teaching scheme
Lecture: - 3 h/week

Course Code	**2ES14**
Course Name	**WIND ENERGY CONVERSION SYSTEMS**

Course objectives:

- To understand the fundamentals of wind energy and its conversion system
- To learn gear coupled generator wind turbine components
- To learn modern wind turbine control & monitoring.

LECTURE WITH BREAKUP

Unit1:

Wind Energy Fundamentals & Wind Measurements:

Wind Energy Basics, Wind Speeds and scales, Terrain, Roughness, Wind Mechanics, Power Content, Class of wind turbines, Atmospheric Boundary Layers, Turbulence. Instrumentation for wind measurements, Wind data analysis, tabulation, Wind resource estimation, Betz's Limit, Turbulence Analysis.

Unit 2:

Aerodynamics Theory & Wind Turbine Types:

Airfoil terminology, Blade element theory, Blade design, Rotor performance and dynamics, Balancing technique (Rotor & Blade), Types of loads; Sources of loads 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.

Unit 3:

Gear Coupled Generator Wind Turbine Components And Their Construction:

Electronics Sensors/Encoder/Resolvers, Wind Measurement : Anemometer & Wind Vane, Grid Synchronisation System, Soft Starter, Switchgear[ACB/VCB], Transformer, Cables and assembly, Compensation Panel, Programmable Logic Control, UPS, Yaw & Pitch System : AC Drives, Safety Chain Circuits, Generator Rotor Resistor controller (Flexi Slip), Differential Protection Relay for Generator, Battery/Super Capacitor Charger & Batteries/ Super Capacitor for Pitch System, Transient Suppressor/Lightning Arrestors, Oscillation & Vibration sensing.

Unit 4:

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 Unit (Voltage and Current), Transformer, Safety Chain Circuits

Unit 5:

Modern Wind Turbine Control & Monitoring System:

Details of Pitch System & Control Algorithms, Protections used & Safety Consideration in Wind turbines, Wind Turbine Monitoring with Error codes, SCADA & Databases: Remote Monitoring and Generation Reports, Operation & Maintenance for Product Life Cycle, Balancing technique (Rotor & Blade), FACTS control & LVRT & New trends for new Grid Codes.

COURSE OUTCOMES	
Student will be able to: 1. Know the energy conversion techniques in wind energy 2. Learn about wind turbine components and their constructions. 3. Understand the modern wind turbine control & monitoring.	

Text Books:

1. Renewable Energy Sources, Twidell J.W. and Weir A., EFN Spon Ltd., 1983.
2. Renewable Energy, Power for a Sustainable Future, Godfrey Boyle Oxford University Press, 1996.

References Books:

1. C-Wet: Wind Energy Resources Survey in India VI.
2 Solar Engineering of Thermal Processes, Duffie A. and Beckmann W. A., John Wiley, 1991.
3. Wind Energy Conversion Systems, Freris L.L., Prentice Hall, 1990.
4. Wind Energy Systems, John D Sorensen and Jens N Sorensen, Woodhead Publishing Ltd, 2011.
5. Stand – alone and Hybrid Wind Energy Systems, Kaldellis J.K., CRC Press, 2010.
6. Wind Energy Systems, Mario Garcia –Sanz, Constantine H. Houpis, CRC Press 2012.
7. Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, Spera D.A., ASME Press, 1994.

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SOLAR ENERGY APPLICATIONS
(Program Elective-IV)

Teaching scheme
Lecture: - 3 h/week

Course Code	**2ES14**
Course Name	**SOLAR ENERGY APPLICATIONS**

Course objectives:

- To clarify impression of various solar thermal energy collectors
- To delineate the other applications and the devices used to collect solar energy
- To summarize the basic economics of solar energy collection system

LECTURE WITH BREAKUP

Unit1:

Solar Flat Plate Collectors: Introduction-Classification - Material involved - Configuration of FPC - Fins and its efficiency- Thermal analysis- Heat transfer coefficients- Various Losses - Testing and performance - Effect of heat capacity and dust - Evolution of evacuated tubes solar collector- Concentrated collectors - Storage Tank - Solar Fluids.

Unit 2:

Solar Water Heating Systems: Integral Collector Storage System - Thermosyphon System - Open Loop, Drain Down, Drain Back, Antifreeze Systems - Refrigerant Solar Water Heaters - Solar Heated Pools - Solar Heated Hot Tubs and Spas.

SOLAR DISTILLATION: Introduction, Working principal, Thermal efficiency, Instantaneous. efficiency, overall thermal efficiency, Heat transfer, External heat transfer, Top loss coefficient, Bottom and Side loss coefficient, Internal heat transfer, Radiative loss coefficient, Convective loss coefficient, Evaporative loss coefficient, Determination of distillate output, Passive solar stills, Effect of various parameters, other designs, Modified internal heat transfer.

Unit 3:

SOLAR AIR HEATERS: Description and classification, Conventional heaters, Double exposure heaters, Air heaters with flow above and both sides of the absorbers, Two pass solar air heater, Heater with finned absorber, Yee-Corrugated absorber, Reverse absorber heater, with porous absorber, Testing of solar air collector, Parametric studies, Application of air heaters, Comparision and performance of liquid and air collector

SOLAR CROP DRYING: Introduction, working principal, Classification, Energy Balancing, Modelling, Moisture content, Drying characteristics curves, Energy requirement, Designing

Unit 4:

Solar cooker: Types-Working principle- Comparison -various phases of cooking, Performance evaluation.

Solar Space Conditioning Systems: Liquid Type Solar Heating System With / Without Storage - Heat Storage Configurations - Heat Delivery Methods - Solar Refrigeration and Air Conditioning.

Other Applications: Solar Ponds – Solar Passive Architecture – Solar Chimney- Use of AI, ML, Block chain and IOT.

Unit 5:

Energy Storage: Energy Storage materials- Sensible heat storage – Phase change materials

Economic Analysis: Cost analysis, Cash flow diagram - Application of economic methods to analyze the feasibility of solar systems to decide project / policy alternatives - Net energy analysis - and cost requirements for active and passive heating and cooling - for electric power generation - and

for industrial process-heating - Payback time with and without interest, Benefit cost analysis, Effect of depreciation, Cost comparison after taxes.

COURSE OUTCOMES	
1. The impression of various solar thermal energy collectors were clarified. 2. The other applications and the devices used to collect solar energy were incorporated. 3. The basic economics of solar energy collection system was understood.	

Text Books:

1. Physics and Technology of Solar Energy- Volume I: Solar Thermal Applications, H P Garg, M Dayal, G Furlan,Springer, 2007.
2. Solar Energy: Principles Of Thermal Collection And Storage, Sukhatme and Nayak, " Tata McGraw.Hill, 2008.
3. Solar Water Heating, Bob Ramlow & Benjamin Nusz, New Society Publishing, 2006.

References Books:

1. Solar Thermal Energy, John Canivan,Sunny Future Press - 2003.
2. "Concentrated Solar Thermal Energy, Charles Christopher Newton, Published by VDM Verlag, 2008.
3. Solar Thermal Energy Storage, H.P.Garg, S.C.Mullick, A.K.Bhargava, D.Reidal, Springer, 2005.
4. Solar Energy Houses: Strategies, Technologies Examples, Anne Grete Hestnes, Robert Hastings, Bjarne Saxhof, Earthscan Publications, 2003.
5. Saroj Kaushik, Artificial Intelligence, Cengage Learning, 1st Edition 2011.
6. Tom Mitchell, Machine Learning, McGraw Hill, 2017
7. Tiana Laurence, Blockchain for Dummies, 2nd Edition 2019, John Wiley & Sons.
8. Internet of Things, RMD Sundaram Shriram K Vasudevan, Abhishek S Nagarajan, John Wiley & Sons.

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M. Tech. I Year II-Sem (Energy Systems)

L	T	P	C
2	0	0	0

VALUE EDUCATION
(Audit Course)

Teaching scheme
Lecture: - 3 h/week

Course Code	**2A113**
Course Name	**VALUE EDUCATION**

Course objectives:
Students will be able to • Understand value of education and self- development • Imbibe good values • Know about the importance of character.

LECTURE WITH BREAKUP
Unit 1: Values and Self-development – Social Values and Individual Attitudes. Work Ethics, Indian Vision of Humanism. Ethical Standards and Principles. Value Judgments.
Unit 2: Importance of Cultivating Values. Sense of Duty. Devotion, Self-reliance, Confidence, Concentration. Truthfulness, Cleanliness. Honesty, Humanity. National Unity. Patriotism. Love for Nature, Discipline.
Unit 3: Personality and Behavior Development - Soul and Scientific Attitude- Integrity and Discipline. Punctuality- Compassion and Benevolence - Positive Thinking- Composure and Equipoise- Dignity of Labour.
Unit4: Universal Brotherhood and Religious Tolerance. True Friendship. Happiness Vs Suffering- Aware of Self-destructive Habits. Association and Cooperation. Eco-friendly Consciousness.
Unit5: Character and Competence – Values of Scriptures- Self-management and Good health. Science of Reincarnation. Equality, Nonviolence, Humility, Role of Women- Secular Thinking- Mind your Mind, Self-control- Non Ethnocentric Behavior.

COURSE OUTCOMES	
Students will be able to 1. Acquire knowledge about self-development 2. Learn the importance of Human values 3. Develop the overall personality	

Text Books:-

1. Chakroborty, S.K. "*Values and Ethics for organizations Theory and practice*", Oxford University Press, New Delhi. 1998.
2. Dostoyevsky, Fyodor, Constance Garnett, and Ernest J. Simmons. *Crime and Punishment*. New York: Modern Library, 1950. Print.
3. Galsworthy, John. *Justice***.** Czechia, Good Press, 2019.
4. TED Talks

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M. Tech. I Year II-Sem (Energy Systems)

L	T	P	C
0	0	4	2

ENERGY CONVERSION LABORATORY

Teaching scheme
Lecture: - 3 h/week

Course Code	**2ES07**
Course Name	**ENERGY CONVERSION LABORATORY**

Course objective:
• To have knowledge of energy conversion principles from one to another.

LECTURE WITH BREAKUP
Study of: 1. Measurement of temperature using Infrared Thermometers 2. Measurement of illumination using Lux meter 3. Exhaust gas analysis using gas analyzer
Experiments: **Experiments:** **1.** To measure the Short circuit current, open circuit voltage and I-V characteristics of solar cell by varying the load using solar simulator apparatus. **2.** To determine the I-V characteristics of a solar cell by varying the illumination using solar simulator apparatus. (at minimum and maximum load resistances) **3.** To determine the I-V characteristics of two solar cells connected in series and parallel. (at minimum and maximum load resistances) **4.** To determine the I-V characteristics at different temperatures of a solar cell using solar simulator apparatus. **5.** To determine the I-V characteristics of a solar panel connected in series and parallel under actual conditions. (at minimum and maximum load resistances) **6.** To determine the power output from a solar cell at different wavelengths using various colour filters. **7.** To determine the Intensity of light energy (lux) at various input conditions at fixed distance from the source. **8.** To determine the Intensity of light (lux) at various distances from the source. **9.** To determine the I-V characteristics of a solar module in the Fuel cell apparatus. **10.** To determine Photocurrent as a function of Distance and Angle of Incidence of the Light Source. **11.** To determine the natural convection heat transfer from a fin assembly. **12.** To determine the temperature distribution in a fin. **13.** To determine the free convection heat transfer of water. **14.** To determine the forced convection heat transfer in a spiral flow. **15.** To determine the forced convection heat transfer in a horizontal tube. **16.** To determine the voltage and current of PV module under tracking condition.

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L	T	P	C
0	0	4	2

COMPUTER SIMULATION LABORATORY

Teaching scheme
Lecture: - 3 h/week

Course Code	**2ES08**
Course Name	**COMPUER SIMULATION LABORATORY**

Course objective

LECTURE WITH BREAKUP

MATLAB:

1. Basic Operations on Matrices.
2. Generation of Various Signals and Sequences (Periodic and Aperiodic), such as Unit Impulse, Unit Step, Square, Saw tooth, Triangular, Sinusoidal, Ramp, Sinc.
3. Familiarization with matlab control system tool box, matlab/simulink tool box.
4. Determination of step & impulse response for a first order unity feedback system
5. Determination of step & impulse response for a second order unity feedback system
6. Determination of bode plot using matlab control system toolbox for 2nd order system &obtain controller specification parameters.
7. Determination of root locus plot using matlab control system toolbox for 2nd order system & obtain controller specification parameters.
8. Determination of nyquist plot using matlab control system toolbox.
9. Study the effect of pi & pd controller on system performance to determine:
   i. Effect of PI controller on system performance
   ii. Effect of PD controller on system performance
9. study the effect of addition of zeros to the forward path transfer function of a closed loop system.
10. Simulation of vertical axis wind turbine.

SIMULATION:

1. Single phase half-controlled converter using R and RL load using MATLAB / SIMULINK
2 Single phase fully controlled converter using R and RL loadusing MATLAB / SIMULINK
3 Three phase fully controlled converter using R and RL load using MATLAB / SIMULINK
4 Single phase AC voltage regulator using MATLAB /SIMULINK

5. Simulation study on Solar PV Energy System.
6. Experiment on “VI-Characteristics and Efficiency of 1kWp Solar PV System”.
7. Simulation study on Wind Energy Generator.
8. Experiment on Performance assessment of micro–Wind Energy Generator.
9. Simulation study on Hybrid (Solar-Wind) Power System.
10. Simulation study on Hydel Power.

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M. Tech. I Year II-Sem (Energy Systems)	**L**	**T**	**P**	**C**
TECHNICAL SEMINAR	**0**	**0**	**4**	**2**

Teaching scheme
Lecture: - 3 h/week

Course Code	**2ES09**
Course Name	**TECHNICAL SEMINAR**

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M. Tech. II Year III- Sem (Energy Systems)

L	T	P	C
3	0	0	3

ENERGY STORAGE SYSTEMS
(Program Elective-V)

Teaching scheme
Lecture: - 3 h/week

Course Code	**3ES15**
Course Name	**ENERGY STORAGE SYSTEMS**

Course objectives:

- To understand the concept of understand / analyse the various types of energy storage.
- To study the various applications of energy storage systems

LECTURE WITH BREAKUP

Unit 1:

Introduction: Necessity of Energy Storage -Types of energy storage (Electrical Energy Storage, Chemical Energy Storage, Thermal Energy Storage, Mechanical Energy Storage, Electrochemical Energy Storage, Thermo-chemical Energy Storage, Thermo-mechanical Energy Storage) -comparison of energy storage technologies – Utilization of energy storage devices -specific areas of applications of energy storage system-Applications.

Unit 2:

Electrical Energy Storage (EES) Technologies and Considerations: Flywheel Energy Storage System (FESS) and Applications; Electrochemical Energy Storage Systems (EESSs): Battery Energy Storage Systems (BESSs) and Applications, Electrical and magnetic energy storage; Capacitor Energy Storage Systems.

Fundamental Concepts of Batteries: Measuring of battery performance - Charging and discharging of a battery - Storage density - Energy density - Safety issues - Types of batteries - Lead Acid, Nickel, Cadmium, Zinc Manganese dioxide and modern batteries for example (i) Zinc-Air (ii) Nickel Metal Hydride (iii) Lithium Ion Battery (iv) Flow Batteries . Brief overview of a) Nanobolt Lithium Tungsten b)Organosilicon electrolyte batteries c) Gold nanowire gel electrolyte batteries and d) Tank Two string cell batteries - Electric Vehicle Battery Charging Stations.

Unit 3:

Pumped Hydro Energy Storage Systems (PHESSs)- KE and Compressed Air Energy Storage Systems- Thermal energy storage with Packed beds - Modelling using porous medium approach -Thermo-chemical energy storage- Fuel cells as energy storage systems - Hydrogen storage methods and types (Metal hydrides, metallic alloy hydrides).

Unit 4:

Thermal energy storage - Necessity, latent heat storage system, Phase Change Materials (PCMs) and classifications, properties of the PCM's for different temperature range, selection criteria of PCMs for heating and cooling in buildings, PCM's use in Solar dryer, water heating system, LHTES systems in refrigeration and air-conditioning applications; Short term heat storage system, Heat storage in solar heating systems (SHS); SHS mediums, Rock-bed storage systems; Energy analysis of the latent heat storage based different systems.

Thermal Storage: Types - Modelling of thermal storage units - Simple water and rock bed storage.

Unit 5:

Case studies: Application of the thermal energy storage for space heating and cooling (Thromb wall), green house heating, Solar power plant applications; Drying and heating for process industries, Food preservation; Waste heat recovery; Comparison of different energy storage technologies and future prospects.

COURSE OUTCOMES	

Students will be

1. Understand the evaluate the different types of the energy storage systems.
2. Analyze different PCM's based energy storage systems including latent heat storage systems and sensible heat storage systems.
3. Analyze the importance of chemical energy storage and hydrogen energy storage.
4. Able to analyse various types of energy storage devices and perform the selection based on techno economic view point.

Text Books:

1. Ataer, O. Ercan. Energy Storage Systems-Volume I (2009): 97, Encyclopedia of Life Support Systems.
2. Kalaiselvam, S., and R. Parameshwaran. Thermal Energy Storage Technologies for Sustainability: Systems Design, Assessment and Applications. Elsevier.
3. Fleischer, Amy S. Thermal Energy Storage Using Phase Change Material, Springer.
4. Solar Energy – Principles of thermal collection and storage, S. P Sukhatme & J. K. Naik. Tata Mc Graw Hill.
5. Thermal Energy Storage Systems and Applications, Ibrahim Dincer and Mark A. Rosen, John Wiley & Sons 2002.
6. Electric Vehicle Technology Explained, James Larminie, John Lowry, Wiley Aug 2012 updated
7. Handbook of Electric Vehicle Charging Infrastructure Implementation , Publication by NITI AYOG, MOP et al
8. https://www.gray.com/insights/5-new-battery-technologies-that-will-change-the-future/

References Books:

1. 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.
2. Francisco Díaz-González, Andreas Sumper, Oriol Gomis-Bellmunt," Energy Storage in Power Systems" Wiley Publication, ISBN: 978-1-118-97130-7, Mar 2016.
3. A. R. Pendse, "Energy Storage Science and Technology", SBS Publishers & Distributors Pvt. Ltd., New Delhi, (ISBN – 13:9789380090122), 2011.
4. Electric Power Research Institute (USA), "Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits" (1020676), December 2010.
5. Paul Denholm, Erik Ela, Brendan Kirby and Michael Milligan, "The Role of Energy Storage with Renewable Electricity Generation", National Renewable Energy Laboratory (NREL) – A National Laboratory of the U.S. Department of Energy – Technical Report NREL/ TP6A2-47187, January 2010.
6. Solar Engg. Thermal Procession, Buffa & Buckman
7. Non-Conventional Energy Sources, G.D. Rai
8. Engg. Technology, S. Rao & D.B Parulkar
9. Electrochemical technologies for energy storage and conversion, Ru-shiliu, Leizhang, Xueliang sun, Wiley publications, 2012
10. Fuel Cells – Principles and Applications, Viswanathan, B and M Aulice Scibioh, Universities Press (2006).
11. Hydrogen and Fuel Cells: A Comprehensive Guide, Rebecca L. and Busby, Penn Well
12. Corporation, Oklahoma (2005).
13. Hydrogen and Fuel Cells: Emerging Technologies and Applications, Bent Sorensen (Sorensen), Elsevier, UK (2005).
14. Linden's Handbook of Batteries , 5th Edition, Kirby W. Beard. Mcgraw Hill Education, May 2019

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M. Tech. II Year III-Sem (Energy Systems) **L T P C**

3 0 0 3

SMART GRID TECHNOLOGIES

(Program Elective - V)

Teaching scheme
Lecture: - 3 h/week

Course Code	**3ES15**
Course Name	**SMART GRID TECHNOLOGIES**

Course objectives:

- To understand concept of smart grid and its developments.
- To understand smart grid technologies and application of smart grid concept in hybrid electric vehicles etc.
- To have Knowledge on smart substations, feeder automation and application for monitoring and protection.
- To have knowledge on micro grids and distributed energy systems.
- To know power quality aspects in smart grid.

LECTURE WITH BREAKUP

Unit 1:

Introduction to Smart Grid: Evolution of electric grid - Concept of smart grid - Definitions – Need of smart grid - Functions of smart grid – Opportunities & barrier of smart grid - Difference between conventional & smart grid - Concept of resilient & self-healing grid - present development & international policies on smart grid – case study of smart grid.

Unit 2:

Smart Grid Technologies-I: Introduction to smart meters- Real time prizing – Smart appliances - Automatic Meter Reading (AMR)- Outage Management Systems (OMS)- Plug In Hybrid Electric Vehicles(PHEV)-Vehicle to grid- Smart sensors- Home & building automation.

Unit 3:

Smart Grid Technologies-II: Smart Substations – Substation automation – Feeder automation – Intelligent Electronic Devices (IED) & their application for monitoring & protection – Smart storage like battery – SMES - Pumped hydro – Compressed air energy storage – Wide Area Measurement System (WAMS) - Phasor Measurement Unit (PMU).

Unit 4:

Micro grids and Distributed Energy Resources: Concept of micro grid- Need & applications of micro grid- Formation of micro grid- Issues of interconnection – Protection & control of micro grid- Plastic & organic solar cells- Thin film solar cells – Variable speed wind generators- Fuel cells- Micro turbines- Captive power plants- Integration of renewable energy sources-Concepts of Islanding.

Unit 5:

Information and Communication Technology for Smart Grid: Advanced Metering Infrastructure (AMI) - Home Area Network (HAN) - Neighbourhood Area Network (NAN) - Wide Area Network (WAN).

COURSE OUTCOMES	
Student can:	

1. Understand smart grids and analyze grid policies and development in smart grids.
2. Develop concepts of smart grid technologies in hybrid electrical vehicles etc.
3. Understand smart substation, feeder automation, GIS etc.
4. Analyze micro grids and distributed generation systems.
5. Analyze the effect of power quality in smart grid and to understand latest developments in ICT for smart grid.

Text Books:

1. Integration of Green and Renewable Energy in Electric Power Systems, Ali Keyhani, Mohammad N. Marwail, Min Dai Wiley.
2. The Smart Grid: Enabling Energy Efficiency and Demand Response, Clark W. Gellings, CRC Press.
3. Smart Grid: Technology and Applications, Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, Wiley.
4. Smart Grids, Jean Clude Sabonnadiere, Nouredine Hadjsaid, Wiley Blackwell.
5. Smart Power : Climate Changes the Smart Grid, and the Future of Electric Utilities, Peter S. Fox Penner, Island Press; 1 edition 8 Jun 2010.
6. Microgrids and Active Distribution Networks, S. Chowdhury, S.P. Chowdhury, P. Crossley, Institution of Engineering and Technology, 30 Jun 2009.
7. Smart Grids (Power Engineering), Smart Borlase, CRC Press.

Reference Books:

1. The Advanced Smart Grid: Edge Power Driving Sustainability: 1, Andres Carvallo, John Cooper, Artech House Publisher July 2011.
2. Control and Automation of Electric power Distribution Systems (Power Engineering), James Northcote, Green, Robert G. Wilson CRC Press.
3. Substation Automation (Power Electronics and Power Systems), MladenKezunovic, Mark G.Adamiak, Alexander P. Apostolov, Jeffrey George Gilbert Springer.
4. Electrcial Power System Quality, R.C.Durgan, Mark F. McGranghan, Surya Santoso, H. Wayne Beaty, 2nd Edition, McGraw Hill Publication.
5. Communication and Networking in Smart Grids, Yang Xiao, CRC Press.

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M. Tech. II Year III- Sem (Energy Systems) **L T P C**

3 0 0 3

HYDROGEN AND FUEL CELLS

(Program Elective-V)

Teaching scheme

Lecture: - 3 h/week

Course Code	**3ES15**
Course Name	**HYDROGEN AND FUEL CELLS**

Course objective:
• To introduce to emerging technologies like production and storage of Hydrogen

LECTURE WITH BREAKUP
Unit1: **Hydrogen Energy Economy:** Hydrogen Energy Economy – Conception, Present status and a vision – Applications of Hydrogen - Transport application-cars, light trucks, buses - Stationary and Portable-Electronic gadgets.
Unit 2: **Hydrogen and Production Techniques:** Hydrogen – Physical and chemical properties, salient characteristics - Production of hydrogen – Steam reforming – Water electrolysis – Gasification and woody biomass conversion – Biological hydrogen production – Photo dissociation – Direct thermal or catalytic splitting of water.
Unit 3: **Hydrogen Storage & Transport:** Hydrogen storage options – Compressed gas – Liquid hydrogen – Hydride – Chemical Storage – Comparisons - Transport of Hydrogen - Pipelines, gaseous, liquid and compound materials.
Unit 4: **Fuel Cells:** History – Principle - Working - Thermodynamics and kinetics of fuel cell process – Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC – Relative merits and demerits - Performance evaluation of fuel cell – Comparison of battery Vs fuel cell – Flow Battery.
Unit 5: **Application Of Fuel Cell:** Fuel cell usage for domestic power systems - Large scale power generation – Automobile - Space - Environmental analysis of usage of Hydrogen in Fuel cell - Future trends in fuel cells.

COURSE OUTCOME	
Students gets 1. Exposure to different fuel cells in particularly Hydrogen fuel cells	

Text Books:

1. Hydrogen and Fuel Cells: A Comprehensive Guide, Rebecca L. and Busby, Penn Well Corporation, Oklahoma (2005).
2. Fuel Cells – Principles and Applications, Viswanathan, B and M Aulice Scibioh, Universities Press (2006).

Reference Books:

1. Hydrogen and Fuel Cells: A Comprehensive Guide, Rebecca L. and Busby, Penn Well Corporation, Oklahoma (2005) **.**
2. Hydrogen and Fuel Cells: Emerging Technologies and Applications, Bent Sorensen (Sørensen), Elsevier, UK (2005) **.**
3. Fuel Cell and Their Applications, Kordesch, K and G.Simader, Wiley-Vch, Germany (1996).
4. Fuel Cells: Theory and Application, Hart, A.B and G.J.Womack, Prentice Hall, NewYork Ltd., London (1989).
5. The Hydrogen Economy, Jeremy Rifkin, Penguin Group, USA (2002).
6. Fuel Cells – Principles and Applications, Viswanathan, B and M Aulice Scibioh, Universities Press (2006).

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3 0 0 3

WASTE TO ENERGY

(Open Elective)

Teaching scheme
Lecture: - 3 h/week

Course Code	**3ES02**
Course Name	**WASTE TO ENERGY**

Course objective
1. To discuss the methods of converting waste into energy through biomass conversion

LECTURE WITH BREAKUP
Unit-1: **Introduction to Energy from Waste:** Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors
Unit-2: **Biomass Pyrolysis:** Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods - Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.
Unit-3: **Biomass Gasification:** Gasifiers – Fixed bed system – Downdraft and updraft gasifiers – Fluidized bed gasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating – Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.
Unit-4: **Biomass Combustion:** Biomass stoves – Improved chullahs, types, some exotic designs, Fixed bed combustors, Types, inclined grate combustors, Fluidized bed combustors, Design, Construction and operation - Operation of all the above biomass combustors.
Unit 5: **Biogas:** Properties of biogas (Calorific value and composition) - Biogas plant technology and status - Bio energy system - Design and constructional features - Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - Direct combustion - biomass gasification - pyrolysis and liquefaction - biochemical conversion - anaerobic digestion Types of biogas Plants – Applications - Alcohol production from biomass - Bio diesel production - Urban waste to energy conversion - Biomass energy programme in India.

Reference Books:

1. Non Conventional Energy, Desai, Ashok V., Wiley Eastern Ltd., 1990.
2. Biogas Technology - A Practical Hand Book - Khandelwal, K. C. and Mahdi, S. S., Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983.
3. Food, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991.
4. Biomass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996.