ACADEMIC REGULATIONS COURSE STRUCTURE AND DETAILED SYLLABUS

CENTRE FOR ENERGY STUDIES

For

M. Tech. (Energy Systems)

(Two Year **Full Time** Programme)

JNTUH COLLEGE OF ENGINEERING HYDERABAD
(Autonomous)
Kukatpally, Hyderabad – 500 085, Telangana, India.

2015

JNTUH COLLEGE OF ENGINEERING HYDERABAD
M.Tech. (Energy Systems) – Full Time w.e.f. 2015-16

I – SEMESTER

S.No.	Subject	L	T	P	Credits
ES 101	Applied Thermodynamics and Energy Conversion	4	0	0	4
ES 102	Advanced Heat Transfer	4	0	0	4
	Elective – 1	4	0	0	4
	Elective – 2	4	0	0	4
	Elective – 3	4	0	0	4
	Elective – 4	4	0	0	4
ES Lab	Modeling and simulation Laboratory	0	0	4	2
	Soft skills Lab	0	0	4	2
	Total Credits				**28**

II – SEMESTER

S.No.	Subject	L	T	P	Credits
ES 201	Energy Management and Conservation	4	0	0	4
ES 202	Photovoltaic and Solar Thermal Systems	4	0	0	4
	Elective – 5	4	0	0	4
	Elective – 6	4	0	0	4
	Elective – 7	4	0	0	4
	Elective – 8	4	0	0	4
ES Lab	Energy Systems Laboratory	0	0	4	2
	Seminar	0	0	4	2
	Total Credits				**28**

III – SEMESTER

S.No.	Subject	L	T	P	Credits
1	Comprehensive Viva Voce				4
2	Project Phase – I				12
	Total Credits				**16**

IV – SEMESTER

S.No.	Subject	L	T	P	Credits
1	Project Phase – II & Dissertation				18
	Total Credits				**18**

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Elective -1
ES 103 - Energy Audit and Management
ES 104 - Thermal Power Plants
ES 105 - Environmental pollution and control

Elective -2
ES 106 - Renewable Energy Technologies
ES 107 - Energy Management in Building
ES 108 - Materials for solar Photovoltaics

Elective -3
ES 109 - Industrial Instrumentation and Control Engineering
ES 110 - Energy Conversion Systems
ES 111 - Energy Storage Devices

Elective-4
ES 112 - Computational Methods
ES 113 - IC Engines and Alternative Fuels
ES 114 - Biomass Conversion and Technologies
ES 115 - Design of Experiments

Elective -5
ES 203 - Design and Optimisation of Energy Systems
ES 204 - Energy Scenario and Energy Policy
ES 205 - Cogeneration and Hybrid Vehicles

Elective -6
ES 206 - Nuclear Energy and its Applications
ES 207 - Solar Refrigeration and Air Conditioning
ES 208 - Hydrogen and Fuel Cells

Elective -7
ES 209 - Advanced Control Systems
ES 210 - Industrial Waste Management and Recycling
ES 211 - Integration of Renewable energy sources

Elective -8
ES 212 - Bio Conversion and Processing of waste
ES 213 - Pollution control in power plants
ES 214 - Computational Fluid Dynamics
ES 215 - Smart Grid Technologies

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

L	T	P	C
4	0	0	4

ES – 101 ADVANCED THERMODYNAMICS AND ENERGY CONVERSION

OBJECTIVES:

- ✓ To understand and apply the concept of availability and to calculate the behavior of real gases
- ✓ 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.

OUTCOMES:

- ✓ Students will able to calculate the availability of the systems and cycles
- ✓ Analyze the engineering systems to improve and optimize its performance
- ✓ Understand the working and the design principles of combustion systems and refrigeration systems.

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.

2. **Properties Of Working Substances:** Pure substance – phases – phase change process – property diagrams – Ideal Gas equation of state – Real gas behavior - Compressibility factor – properties - Composition of a Gas mixture – mass and mole fractions – Properties of gas mixtures (Ideal and Real gases) - Maxwell's relations - Clausius Clayperon equation – General relations for du, dh, ds, C_v ,C_p for ideal gases (pure substances) and real gases (No derivations and problems) - Theoretical and actual combustion processes – Enthalpy of formation – Enthalpy of Combustion.

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

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.

5. **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 - working – governing - parameters.

Reference Books:

a. Thermodynamics – An Engineering Approach / Y.A.Cengel and Mc. A. Boles/
b. Basic and Applied Thermodynamics / P.K.Nag /TMH
c. Thermodynamics / Sontag & Van Wylen
d. Thermodynamics / YVC RAO.
e. Introduction to the Thermodynamics of Materials – David R. Gaskell

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L	T	P	C
4	0	0	4

ES – 102 ADVANCED HEAT TRANSFER

OBJECTIVES:
- ✓ To understand the laws of fluid flow and Heat transfer
- ✓ To develop the skills to correlate the Physics with applications

OUTCOME:
- ✓ Student will be able to use the concepts of Heat Transfer and fluid flow in the field of energy applications.

1. **Conduction:** Introduction – Modes of heat transfer – Combined modes – Steady one-dimensional – Steady heat source system – Steady porous system – Steady two-dimensional system – Unsteady Conduction - Lumped heat capacity system - infinite solid flat plate - cylinder (Hcsillery charts).

2. **Fins:** Types of fins – Analysis of fins (Longitudinal & annular) of uniform cross section, effectiveness - Efficiency of fin.

3. **Convection:** Boundary layer flow with heat transfer - Equations of momentum and energy – Forced convection over a flat plate (similarity solution) – Empirical relations for forced and free convection - Mechanism of free convection in enclosed spaces – Mixed convection.

4. **Two Phase Heat Transfer:** Regimes of pool boiling – Flow boiling – Correlations - Types of condensation – Film condensation on horizontal and vertical surfaces.

5. **Radiation:** Overview of Mechanism – laws of radiation- Radiant heat exchange in gray - non-gray bodies - with transmitting - reflecting and absorbing media - specular surfaces - gas radiation
   Heat Exchanger: Definition and classification - 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 – compact heat exchangers.

Reference Books:

a. Holman.J.P., Heat Transfer, Tata Mc Graw Hill, 2002.
b. Engineering heat and mass transfer by Mahesh M Rathore, Laxmi Publications
c. Heat Transfer - A basic approach / Necati Ozisik/ Mc Graw Hill
d. Heat transfer by Cengel and Ghajar, TMH
e. Fundamentals of Heat and Mass transfer by Incropera and Dewit, Wiley
f. Heat Transfer / Ghoshdastidar / Oxford University Press
g. Convective Heat Transfer Analysis /Patrick H.Oosthuizen/David Naylor/ Mc Graw Hill
h. Convective Heat and Mass Transfer / W.M.Kays & Craford/ TMH
i. Mass Transfer Operations / Robert E. Treybal / Mc Graw Hill

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ES – 103 ENERGY AUDIT AND MANAGEMENT
(Elective-1)

OBJECTIVES:
- ✓ To understand the energy utilization pattern including wastage and its management.

OUTCOMES:
Student will be able to
- ✓ Carry out the energy audit in any type of building and suggest the relevant and appropriate conservation measures.
- ✓ Suggest the renewable energy systems for the buildings

1. **Introduction:** Basic elements and measurements - Mass and energy balances - Scope of energy auditing industries - Evaluation of energy conserving opportunities.

2. **Energy Audit Concepts:** Need of Energy audit - Types of energy audit - Energy management (audit) approach - understanding energy costs - Bench marking - Energy performance - Matching energy use to requirement - Maximizing system efficiencies - Optimizing the input energy requirements - Duties and responsibilities of energy auditors - Energy audit instruments - Procedures and Techniques.

3. **Principles and Objectives of Energy Management:** Design of Energy Management Programmes - Development of energy management systems – Importance - Indian need of Energy Management - Duties of Energy Manager - Preparation and presentation of energy audit reports - Some case study and potential energy savings.

4. **Thermal Energy Management:** Energy conservation in boilers - steam turbines and industrial heating systems - Application of FBC - Cogeneration and waste heat recovery - Thermal insulation - Heat exchangers and heat pumps - Building Energy Management.

5. **Electrical Energy Management:** Supply side Methods to minimize supply-demand gap - Renovation and modernization of power plants - Reactive power management - HVDC - FACTS - Demand side - Conservation in motors - Pumps and fan systems - Energy efficient motors.

   ***Note:** A case study involving audit may be taken up and a report suggesting improvements which can be considered as a part of assignment.

<u>References Books:</u>

a. Energy Management: W.R.Murphy, G.Mckay 109
b. Energy Management Principles: C.B.Smith
c. Efficient Use of Energy : I.G.C.Dryden
d. Energy Economics A.V.Desai
e. Hamies, Energy Auditing and Conservation; Methods Measurements, Management and Case study, Hemisphere, Washington, 1980.
f. Guide book for National Certification Examination for Energy Managers and Energy Auditors (Could be downloaded from www.energymanagertraining.com).

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L	T	P	C
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ES – 104 THERMAL POWER PLANTS
(Elective-1)

OBJECTIVES:
- ✓ To obtain knowledge on power generation techniques
- ✓ To suggest suitable methods to improve the performance of thermal power plants

OUTCOMES:
Students get
- ✓ Exposure to different cycles and their working principle related to thermal power plants

1. **Fuels and Combustion:** Types of fuels – Coal firing – Pulverization of solid fuels – Fuel handling systems – Coal cycle – Ash cycle – Types of Furnaces – Fluidized Bed Combustion (FBC) – Liquid and gaseous fuels – Byproducts of combustion (simple problems) – Heat of combustion – Combustion temperatures – Stack.

2. **Steam Generators and Accessories:** Steam generators – Classification – Types – High-pressure boilers – Super critical boilers – Steam piping Accessories - Super heaters – Reheaters – 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.

3. **Steam Turbines (Illustrative problems only):** Classification – HP/IP/LP Turbines - Impulse turbines – Reaction turbines – Compounding – Steam compounding – Velocity compounding – Advantages and disadvantages – Governing – Turbine losses – Turbine efficiencies – Turbine materials.

4. **Gas Turbines (Illustrative problems only):** Gas Turbine cycle – Combined cycle analysis – 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

5. **Power Plant Layout, Economics and Environmental Aspects**: General layout of modern thermal power plants – Advanced layout – Plant efficiency and economics.
   Environmental aspects of thermal power plants - Constituents of the atmosphere – Ash and Dust handling - Oxides of Sulfur, Nitrogen and Carbon – Greenhouse effect – Acid precipitation – Particulate matter – Electrostatic precipitators – Thermal pollution

Reference Books:
a. A course in Power Plant Engineering, Arora and Domkundwar, Dhanpat Rai.
b. Power Plant Technology, El Wakil/ Mc Graw Hill.
c. Power Plant Engineering, G.R. Nagpal/Khanna Publishers.
d. Power Plant Technology, Rajput.
e. Power Plant Engineering, P.K.Nag/Tata McGraw Hill.

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ES – 105 ENVIRONMENTAL POLLUTION AND CONTROL
(Elective-1)

OBJECTIVES:

- ✓ To understand the concepts of pollution/pollutants and how to protect it from the environment.

OUTCOMES:

Student will be able to

- ✓ Have knowledge of continual degradation of environment.
- ✓ Have an exposure to different types of pollutions control methods.

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.

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 - 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.

3. **Land Pollution:** 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.

4. **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.

5. **Marine pollution:** Sources and nature of pollutants - Oil pollution - Metallic pollutants - Status of coastal and estuarine pollution in India - Chemicals and drugs from oceans - Sea level rise – Cause - effect.

Reference Books:

a. Environmental Pollution Control Engineering. C. S. Rao, Wiley Eastern Ltd. Delhi 1991.
b. Management of Energy Environment Systems W.K.Foell John Wiley and Sons.
c. Energy Management and Control Systems M.C.Macedo, Jr. John Wiley and Sons.
d. Environmental Impact Analysis Handbook J.G.Rau, D.C.Wood, Mc Graw Hill.
e. Energy & Environment – J.M. Fowler, Mc Graw Hill.

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4	0	0	4

ES – 106 RENEWABLE ENERGY TECHNOLOGIES
(Elective-2)

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 analyze the environmental and cost economics of renewable energy sources in comparison with fossil fuels.

OUTCOMES:
Student have
- ✓ An understanding of renewable energy sources
- ✓ A knowledge of working principle of various energy systems
- ✓ A capability to carry out basic design of renewable energy systems

1. **Global and National Energy Scenario:** Over view of conventional & renewable energy sources - Need & development of renewable energy sources - Types of renewable energy systems - Future of Energy Use - Global and Indian Energy scenario - Renewable and Non-renewable Energy sources, Energy for sustainable development - Potential of renewable energy sources - Renewable electricity and key elements - Global climate change - CO_2 reduction potential of renewable energy- Concept of Hybrid systems.

2. **Solar Energy:** Solar energy system - Solar Radiation – Availability - Measurement and Estimation - Solar Thermal Conversion Devices and Storage - Applications Solar Photovoltaic Conversion - solar thermal - Applications of solar energy systems.

3. **Wind Energy:** Wind Energy Conversion – Potential - Wind energy potential measurement - Site selection - Types of wind turbines - Wind farms - Wind Generation and Control - Nature of the wind - Power in the wind - Factors influencing wind - Wind data and energy estimation - Wind speed monitoring - Classification of wind – Characteristics - Applications of wind turbines - Offshore wind energy – Hybrid systems - Wind resource assessment - Betz limit - Site selection - Wind energy conversion devices - Wind mill component design - Economics and demand side management - Energy wheeling - Energy banking concepts - Safety and environmental aspects - Wind energy potential and installation in India.

4. **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.

5. **Ocean Energy:** Ocean wave energy conversion - Principle of Ocean Thermal Energy Conversion (OTEC) - Ocean thermal power plants - Tidal energy conversion - Tidal and wave energy its scope and development - Scheme of development of tidal energy.

a. **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.
b. **Geothermal Energy**: Geothermal power plants - Various types - Hot springs and steam ejection.

Reference Books:

a. Power plant technology, J Wakhil
b. Non-Conventional Energy Sources G.D Rai
c. Solar Energy - Principles of thermal collection and storage S. P. Sukhatme
d. Solar Engineering of Thermal Processes J. A. Duffie and W. A. Beckman
e. Biomass Regenerable Energy D. D. Hall and R. P. Grover.
f. Renewable Energy Sources, Twidell, J.W. and Weir, A., EFN Spon Ltd., 1986.
g. Renewable Energy Engineering and Technology, Kishore VVN, Teri Press, New Delhi, 2012
h. Sustainable Energy Systems Engineering, Peter Gevorkian, McGraw Hill,2007
i. Principles of Solar Engineering, Kreith, F and Kreider, J. F., McGraw-Hill, 1978.
j. Renewable Energy, Power for a Sustainable Future, Godfrey Boyle, Oxford University Press, U.K, 1996.
k. Alternative Energy Sources, Veziroglu, T.N., Vol 5 and 6, McGraw-Hill, 1990
l. Biochemical and Photosynthetic aspects of Energy Production, Anthony San Pietro, Academic Press, 1980.
m. Thermochemical processing of Biomass, Bridgurater, A.V., Academic Press, 1981.
n. Renewable Energy, Bent Sorensen , Elsevier, Academic Press, 2011

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L	T	P	C
4	0	0	4

ES – 107 ENERGY MANAGEMENT IN BUILDING
(Elective-2)

OBJECTIVES:
- ✓ To explain the concept of energy usage at indoor and at end use.
- ✓ To give a exposure to energy management techniques.

OUTCOMES:
Students get
- ✓ Exposure to Electrical Management in Building at indoor and at outdoor.

1. **Overview Of The Significance Of Energy Use And Energy Processes In Building:** Indoor activities and environmental control - Internal and external factors on energy use and the attributes of the factors - Characteristics of energy use and its management - Macro aspect of energy use in dwellings and its implications – Concepts of energy efficient building.

2. **Indoor Environmental Requirement And Management:** Thermal comfort - Ventilation and air quality - Air-conditioning requirement - Visual perception - Illumination requirement - Auditory requirement – Concept of sick building syndrome – Significance in energy management in buildings.

3. **Climate:** Solar radiation and their influences - The sun-earth relationship and the energy balance on the earth's surface – Climate – Wind - Solar radiation - Temperature - Sun shading and solar radiation on surfaces - Energy impact on the shape and orientation of buildings.

4. **End-Use:** Energy utilization and requirements – Lighting and day lighting – End-use energy requirements – Status of energy use in buildings – Estimation of energy use in a building - Heat gain and thermal performance of building envelope – Steady and non steady heat transfer through the glazed window and the wall – Standards for thermal performance of building envelope – Evaluation of the overall thermal transfer – Concepts of window management.

5. **Energy Management Options:** Energy audit and energy targeting – Technological options for energy management – Modifications for energy efficient buildings for Indian conditions.

Reference Books:

a. Heating and Cooling of Buildings – Design for Efficiency, J. Krieder and A. rabl, McGraw Hill, 1994.
b. Mechanical and Electrical Equipment for Buildings, S. M. Guinnes and Reynolds, Wiley, 1989.
c. Energy Design for Architects, Shaw, Aee Energy Books, 1991.
d. Handbook, of Fundamentals, ASHRAE, Atlanta, 1997.
e. Low Energy Cooling – A Guide to the Practical Application of Passive Cooling and Cooling Energy Conservation Measures, Donald W. Abrams, Van Nostrand Reinhold Co., New York, 1986.
f. Energy Conservation in Buildings – Royal Institute of Architecture, Canada.
g. Publication of CBRI, Roorkee – Energy Management in Buildings.

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4	0	0	4

ES – 108 MATERIALS FOR SOLAR PHOTOVOLTAICS
(Elective-2)

OBJECTIVES:
- ✓ To explain concept of various materials using for photovoltaic cells
- ✓ To expose latest developments in PV technology.

OUTCOME:
Students have
- ✓ Understanding of materials for solar energy.

1. **Introduction:** Different types of materials – Availability – Advantages – Disadvantages - applications.

2. **Solar Cells:** Spectral response of solar cells - Dark conductivity - I-V characterization - Introduction to physics of semiconductor devices.

3. **Basics Of Solar Cells**: High efficiency solar cells - PERL Si solar cell - LGBC solar cell - III-V, II-VI high efficiency solar cells - thin film technology - GaAs solar cells - tandem and multi junction solar cells - solar PV concentrator cells and systems.

4. **Different Materials Used For Solar Cells:** Nano - micro and poly crystalline Si for solar cells - Mono micro silicon composite structure - Silicon and non silicon thin film deposition techniques - Advanced solar cell concepts and technologies - Amorphous silicon thin film technologies - Multi junction solar cells – CDTE – CIGS - Quantum dots - Peroskvite.

5. **Polymers:** Conjugated polymers - Organic/plastic/flexible solar cells - Polymer composites for solar cells - Device fabrication and characterization - Materials and devices for energy storage.
   Batteries - Carbon Nano Tube (CNT) - Fabrication of CNTs - CNTs for hydrogen storage - CNT polymer composites - Ultra capacitors etc - Polymer membranes for fuel cells - PEM fuel cell - Acid/Alkaline fuel cells.

References Books:

a. Solar cells: Operating principles, technology and system applications by Martin A Green, Prentice Hall Inc, Englewood Cliffs, NJ, USA, 1981.
b. Semi conductors for solar cells, HJ Moller, Artech House Inc, MA, USA, 1993.
c. Solid State electronic devices, Ben G Streetman, Prentice Hall of India Pvt Ltd., New Delhi 1995.
d. Carbon nanotubes and related structures: New material for twenty first century, PJF Harris, Cambridge University Press, 1999.
e. Think Film crystalline silicon solar cells: Physics and technology, R. Brendel, Wiley VCH, Weinheim, 2003.
f. Clean Electricity from photovoltaics , M. D. Archer, R. Hill, Imperial college press, 2001.
g. Organic photovoltaics: Concepts and realization, V Barbec, V.Dyakonov, J. Parisi, N.S. Saricifttci, Springer Verlag 2003.
h. Fuel cell and their applications, K. Kordesch, G. Simader, VCH, Weinheim, Germany, 1996.
i. Battery technology handbook, H. A. Kiehne, Marcel Dekker, New York, 1989.

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L	T	P	C
4	0	0	4

ES – 109 INDUSTRIAL INSTRUMENTATION AND CONTROL ENGINEERING (Elective-3)

OBJECTIVES:

- ✓ To understand the principles and use of transducers for measurement of different thermal and electrical parameters.
- ✓ To understand the concepts of control systems, modes and design.

OUTCOMES:

Students obtain

- ✓ knowledge on measurement and control techniques applicable to energy systems

1. **Elements of a Measurement System:** Basic Instrumentation system - Errors and Uncertainties - Mechanical Transducers – Temperature - Bimetallic Element and Fluid Expansion type Thermometers - Pressure- Manometers and Bourdon Gauges - Load Cells and Elastic Force Devices - Electrical transducers - Resistive Transducers - Inductive Transducers - Capacitive transducers - Thermoelectric Transducers and Photoelectric Transducers - Piezoelectric Transducers.

2. **Basic Signal Conditioning Elements:** DC Bridges - AC Bridges - Wheatstone Bridge - Balance & Deflection Measurements – Amplifiers - Non Electrical and Electrical types - Op Amps - Summing – Differential - Charge Amplifiers - Differentiating and Integrating Elements – Filters - Data Transmission Elements- Electrical – Pneumatic - Position and Radio Frequency Transmission types - Basic display elements.

3. **Industrial Measurements Velocity Measurement:** Contact type - AC-DC Tachometers Non contact type – Magnetic - Photoelectric & stroboscopic methods Acceleration measurement – Seismic Accelerometer & Piezoelectric Accelerometer - Measurement of Force – Different methods - Strain gauge load cell method - Measurement of torque – Strain gauge method - Radiation Measurement – Radiation Fundamentals - Radiation detectors - Optical pyrometer.

4. **Control Systems:** Open & Closed loop systems - Linear Time-invariant systems - Transfer Function Analysis - Mason's Gain Formula - Transient response analysis - Concepts of P, PI and PID controllers (Descriptive treatment only) - Stability Analysis - RH Criterion - Relative stability.

5. **Frequency response analysis:** Bode plots - Nyquist Stability Criterion - Gain Margin & Phase Margin (Simple problems only) - Introduction to State Space Analysis (Elementary treatment only – No numerical) - Concept of state - State variables & state models - State transition matrix

   * ***Being a descriptive & inter disciplinary course NO NUMERICALS are envisaged in this course except for unit IV.***

Reference Books:

a. Modern Electronic Instrumentation and Measurement Techniques; Albert D Helfrick and William D Cooper, 2004, PHI.
b. Process Control: Principles and Applications; Surekha Bhanot, Oxford University press, Fourth Impression, 2010.
c. Instrumentation, Measurement and Analysis; BC Nakra, and KK Chaudhry; 2 ed, 2004, Tata McGraw-Hill
d. Transducers and Instrumentation; DVS Murthy, 2003, PHI
e. Instrumentation Devices and Systems; CS Rangan, GR Sarma, and VSV Mani; 2 ed, Tata McGraw-Hill
f. Measurement Systems Application and Design; Doeblin and Ernest; 5 ed, 2004, Tata McGraw-Hill.
g. Measurement Systems – Applications & design; Doeblin E.O. 4th ed. Mc. Graw Hill
h. Principles of Industrial Instrumentation, Patranabis D. TMH – 1997
i. Mechanical & Industrial Measurements, Jain R.K, Khanna Publishers – 1986
j. Process Instruments and control Hand book, Considine D.M, 4th ed, Mc.Graw Hill
k. Instrument Technology – Vol.1m, Jones E.B., Butterworths – 1981
l. Control Systems Engineering, Nagrath & M.Gopal, Wiley Eastern
m. Automatic Control Systems, B.C.Kuo, John Wiley, 2009
n. Modern Control Engineering, Katsuhiko Ogata, Prentice Hall

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L	T	P	C
4	0	0	4

ES – 110 ENERGY CONVERSION SYSTEMS
(Elective-3)

OBJECTIVES:

To analyze the working principle, pros and cons of

- ✓ Conventional energy conversion techniques
- ✓ Direct energy conversion systems
- ✓ Need and necessity of energy storage systems and their desirable characteristics & Fuel cells

OUTCOME:

Students have an

- ✓ Awareness on the existence of various mechanisms for conversion and storage of energy, their merits, constraints and drawbacks

1. **Conversion Cycles:** Reversible and irreversible cycles - Thermodynamics analysis of Carnot - Stirling – Ericsson – Otto – Diesel – Dual – Atkinson - Brayton, Rankine.

2. **Different Types Of Converters:** Fundamentals of converters - Thermoelectric Converters - Thermionic converters – MHD - Ferro electric converter - Nernst effect generator.

3. **Energy Storage Devices:** Different types of Batteries – Working - Performance governing parameters - Hydrogen energy - Solar photovoltaic cells.

4. **Fuel Cells:** Basics – Types – Working - Comparative analysis - Thermodynamics and kinetics of fuel cell process - Performance of fuel cell – Applications - Advantages and drawbacks.

5. **Energy Storage Technologies:** Mechanical energy - Electrical energy - Chemical energy - Thermal Energy.

References Books:

a. Principles of Energy Conversion, Archie.W.Culp, McGraw-Hill Inc., 1991, Singapore.
b. Fuel Cell and Their Applications, Kordesch. K, and Simader.G, Wiley-Vch, Germany 1996.
c. Direct Energy Conversion, Kettari, M.A. Addison-Wesley Pub. Co 1997.
d. G.J.Fuel Cells: Theory and Application, Hart A.B and Womack, Prentice Hall Newyork Ltd., London 1989.

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4	0	0	4

ES – 111 ENERGY STORAGE DEVICES
(Elective-3)

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

OUTCOME:
Students will be
- ✓ Able to analyse various types of energy storage devices and perform the selection based on techno economic view point

1. **Necessity Of Energy Storage**: Types of energy storage – comparison of energy storage technologies - Applications.

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

3. **System Pressurized Water Storage System:** Modelling of phase change storage system - Simple units - Packed bed storage units - Modelling using porous medium approach - Use of Transys.

4. **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 Hydride (iii) Lithium Battery.

5. **Hybrid Storage Devices:** Flywheel - Super capacitors - Principles & Methods – Applications - Compressed air Energy storage - Concept of Hybrid Storage - Applications.

6. **Hydrogen Storage Devices:** Hydrogen storage options – Compressed gas – Liquid hydrogen – Hydride – Chemical Storage – Comparisons - Safety and management of hydrogen - Applications of Hydrogen.

References Books:

a. Solar Engg. Thermal Procession, Buffa & Buckman
b. Solar Energy, G.D. Rai
c. Engg. Technology, S. Rao & D.B Parulkar
d. Solar Energy, Sukhatme
e. Thermal Energy Storage Systems and Applications, Ibrahim Dincer and Mark A. Rosen, John Wiley & Sons 2002.
f. Fuel cell systems Explained, James Larminie and Andrew Dicks, Wiley publications, 2003.
g. Electrochemical technologies for energy storage and conversion, Ru-shiliu, Leizhang, Xueliang sun, Wiley publications, 2012
h. Fuel Cells – Principles and Applications, Viswanathan, B and M Aulice Scibioh, Universities Press (2006).
i. Hydrogen and Fuel Cells: A Comprehensive Guide, Rebecca L. and Busby, Penn Well

Corporation, Oklahoma (2005).
j. Hydrogen and Fuel Cells: Emerging Technologies and Applications, Bent Sorensen (Sorensen), Elsevier, UK (2005).
k. Fuel Cell and Their Applications, Kordesch, K and G.Simader, Wiley-Vch, Germany (1996).
l. Fuel Cells: Theory and Application, Hart, A.B and G.J.Womack, Prentice Hall, NewYork Ltd., London (1989)
m. The Hydrogen Economy, Jeremy Rifkin,Penguin Group, USA (2002).

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

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ES – 112 COMPUTATIONAL METHODS
(Elective-4)

OBJECTIVES:
- ✓ To understand different analytical techniques including Finite Element Methods

OUTCOME:
Students will get an
- ✓ Exposure to different computational methods and their applications to engineering background

1. **Finite Differences:** Forward - Backward and Central difference approximations to derivatives – Croutes method - Jacobi's Method – Gauss Siedel iterative method - Successive over-relaxation method.

2. **Methods Of Engineering Analysis:** Introduction of Treatment of experimental - Analytical and numerical methods - Errors - Truncation and Rounding off - Finite Element Method - Comparison of F E M with Finite Difference methods - Raleigh Ritz method - concept of Potential Energy – Gelarkin's method.

3. **Introduction to FEM:** Basic concepts – Historical background – General Applications of FEM –Steps involved in F E M - Discretization of domain - Basic element shapes and types-Characteristics of finite elements - Location of nodes - Node numbering scheme - Degree of freedom - Interpolation models – Convergence requirements.

4. **Finite Element Modeling:** One dimensional problem - Coordinates and shape functions for 1-D problems – Applications to solid mechanics - Load stress – Strain - Displacement and their relationships - Formulation of stiffness matrix and load vectors - Properties of stiffness matrix –Temperature effects - Some simple problems on 1-D solid mechanics.

5. **Two Dimensional Problems:** Introduction to Plane stress and plane strain - 2-D modeling – Constant strain triangle – Boundary condition – Shape functions for a CST element - Element stiffness matrix - Isoparametric representation - Basic equations of heat transfer - Steady state heat transfer-heat conduction - Some typical problems in heat transfer.

Reference Books:

a. Finite element Methods by Bathe PHI Publication
b. Introduction to Numerical Methods/ S.S.Sastry
c. Numerical Methods /B.S.Grawel
d. Computational Fluid flow and Heat transfer / Edt.K.Muralidhar and T.Sundararajan / Narosa
e. Finite Elements in Engineering / S.S.Rao
f. Introduction to Finite Element Engineering/T.R.Chandrupatla and A.D. Belagundu
g. Finite Element engineering -Jalaluddin

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ES – 113 IC ENGINES AND ALTERNATIVE FUELS
(Elective-4)

OBJECTIVE:
- ✓ To obtain the knowledge on automobile engines their working principles fuels used and their applications

OUTCOME:
- ✓ Students gets exposure for preparation of fuels for different engines

1. **Fuels & Cycle Analysis:** Broad classification of fuels - Thermo-chemistry of Fuel – Air mixtures - properties – Ideal Models of Engine cycles - Engine Types – Design and operating Parameters – Real Engine cycles difference and responsible factors.

2. **Combustion in S.I and C.I Engines:** Normal and Abnormal Combustion - Flame speed and factors influencing it - Factors affecting knock - Combustion in CI engines – Different stages of combustion – knocking in diesel engines – importance of ignition delay – Heat release rate in C.I engines – Factors affecting combustion and knock – Fuel spray in diesel engines and air movement.

3. **Combustion Chambers in S.I & C.I Engines:** Design Principles – Types of combustion chambers – IDI Engines – Comparison of DI & IDI Engines.

4. **Pollutant Formation and Control:** Nature and extent of problems – Nitrogen Oxides - Carbon monoxide - Unburnt Hydrocarbon and particulate emission – Measurement – Exhaust Gas Treatment – Exhaust Gas Recirculation (EGR) - Catalytic converter - 2 way type & 3 way type - Selective Catalytic Reduction (SCR) - NO_x traps.

5. **Modern Trends in IC Engines:** Lean Burning and Adiabatic concepts - Rotary Engines - Modification in IC Engines to suite Bio-Fuels - Fuel supply systems for SI and CI engines to use gaseous fuels like LPG, CNG, and Hydrogen – Common Rail Direct Injection (CRDI) - Homogenous Charge Compression Ignition (HCCI) & Gasoline Direct Injection (GDI).

   * **Note:** This being a descriptive course, numerical problems are not envisaged.

Reference Books:

a. I.C. Engines Fundamentals, Heywood, McGraw Hill
b. I.C. Engines, Ferguson
c. I.C. Engines, Maleev
d. I C Engines, V Ganesan
e. I.C. Engine in theory and Practice Vol. I and II, Taylor
f. I.C. Engines, Obert, Int.Text Book Co.
g. Combustion Engine Processes, Lichty
h. Scavenging of two stroke Cycle Engines, Switzer Fundamentals of I.C Engines, H. N. Gupta, PHI Publishers.

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ES – 114 BIOMASS CONVERSION AND TECHNOLOGIES
(Elective-4)

OBJECTIVES:
- ✓ To have an exposure on the types of biomass, its surplus availability and characteristics.
- ✓ Analyze the technologies available for conversion of biomass to energy in terms of its technical competence and economic implications.

OUTCOME:
Student gets
- ✓ A practical understanding on the various biomass energy conversion technologies and its relevance towards solving the present energy crisis.

1. **Origin of Biomass:** Resources - Classification and characteristics - Techniques for biomass assessment - Application of remote sensing in forest assessment - Biomass estimation.
2. **Thermochemical Conversion:** Different processes - Direct combustion – Incineration – Pyrolysis - Gasification and liquefaction - Economics of thermochemical conversion.
3. **Biological Conversion:** Biodegradation and biodegradability of substrate - Biochemistry and process parameters of biomethanation - Biogas digester types - Digester design and biogas utilization.
   Biomethanation Process - Economics of biogas plant with their environmental and social impacts - Bioconversion of substrates into alcohol - Methanol & ethanol Production - Organic acids – Solvents - Amino acids - Antibiotics etc.
4. **Chemical Conversion:** Hydrolysis & hydrogenation - Solvent extraction of hydrocarbons - Solvolysis of wood - Biocrude and biodiesel - Chemicals from biomass
5. **Power Generation:** Utilisation of gasifier for electricity generation - Operation of spark ignition and compression ignition engine with wood gas – Methanol - ethanol & biogas - Biomass integrated gasification/combined cycles systems - Sustainable cofiring of biomass with coal - Biomass productivity - Energy plantation and power programme.

References Books:

a. Biotechnology and Alternative Technologies for Utilization of Biomass, Chakraverthy A
b. Biogas Systems: Principles and Applications, Mital K.M
c. Biomass Energy Systems, Venkata Ramana P and Srinivas S.N
d. Gasification Technologies, A Primer for Engineers and Scientists Rezaiyan. J and N. P. Cheremisinoff.
e. Biomass Gasification – Principles and Technology, Tom B Reed, Noyce Data Corporation, 1981.
f. Bio Energy Technology Thermodynamics and costs, David Boyles, Ellis Hoknood Chichester,1984.
g. Khandelwal KC, Mahdi SS, Biogas Technology – A Practical Handbook, Tata McGraw Hill, 1986.
h. Bio Energy for Rural Energisation, Mahaeswari, R.C. Concepts Publication,1997
i. Best Practises Manual for Biomass Briquetting, I R E D A, 1997.
j. The briquetting of Agricultural wastes for fuel, Eriksson S. and M. Prior, FAO Energy and Environment paper, 1990.
k. Thermochemical Characterization of Biomass, Iyer PVR , M N E S

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ES – 115 DESIGN OF EXPERIMENTS
(Elective-4)

OBJECTIVES:
- ✓ To get a feel of developing different mathematical models for designing.
- ✓ To obtain an optimization solution after designing a product.

OUTCOME:
Students get
- ✓ An exposure to design and optimize a product or a process.

1. **Total Quality Management:** Quality Function Development – Product and Process Optimization – Process Capability – Basics of DOE.

2. **Need For Planned Experimentation:** Steps in experimentation – Comparison of design of Experiments – Loss function – Response Factors – Levels - Treatment combination – Effect of a factor – Experimental error – Data Analysis.

3. **Experimental Design**: Factorial Experiments – Fractional Factorial Experiments – Taguchi's Method – Orthogonal array - Design and Development – Linear Graph – Interaction effect – Analysis of Variance.

4. **Optimization of Process Parameter**: Optimization strategy – Selection and identification of parameters – Response Graph Analysis – Signal to noise ratio analysis – Gray relational analysis.

5. ***Optimization of Cost and Quality**: Artificial Neural Network – Genetic Algorithms – Simulated Annealing Algorithm – Ant Colony Algorithm – Fuzzy logic approach.
   * Simple treatment only

Reference Books:

a. Design and Analysis of Experiments, Douglus C Montgomery, John Wiley & Sons, 1984.
b. Fundamental concepts in design of experiments, Charles R Hicks, Holt, Rinchort and Winston, 1984.
c. Quality Engineering using robust design, Phadke, M S, Prentice Hall, 1989
d. Taguchi Techniques for quality engineering, Ross J Philip, McGraw Hill, 1989
e. System of Experimental Design, Genichi Taguchi, UNIPUB, Karus International Publication, 1987
f. Optimization for engineering design, Deb, K., Prentice Hall of India, 2005

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MODELING AND SIMULATION LABORATORY

WRITING PROGRAMS AND DEMONSTRATION

1. Declination of earth, hour angle, day length, local apparent time.
2. Monthly average, hourly global and diffuse radiation on a horizontal surface and tilted surfaces.
3. Power generation from a wind turbine, Variation of wind velocity and power with altitude.
4. Solution of ordinary differential eqations-4th order R K Method.
5. Solution of one-dimensional steady state heat conduction equation.
6. Solution of two-dimensional steady state PDE.
7. Solution of one-dimensional transient PDE.

FINITE ELEMENT ANALYSIS

8. Two dimensional heat conduction.
9. One dimensional transient heat conduction.
10. Transient analysis of a casting process.

CFD ANALYSIS

11. Flow through a pipe bend.
12. Flow through a nozzle.

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SOFT SKILLS LAB
(Activity-based)

Course Objectives

- To improve the fluency of students in English
- To facilitate learning through interaction
- To illustrate the role of skills in real-life situations with case studies, role plays etc.
- To train students in group dynamics, body language and various other activities which boost their confidence levels and help in their overall personality development
- To encourage students develop behavioral skills and personal management skills
- To impart training for empowerment, thereby preparing students to become successful professionals

Learning Outcomes

- Developed critical acumen and creative ability besides making them industry- ready.
- Appropriate use of English language while clearly articulating ideas.
- Developing insights into Language and enrich the professional competence of the students.
- Enable students to meet challenges in job and career advancement.

INTRODUCTION

Definition and Introduction to Soft Skills – Hard Skills vs Soft Skills – Significance of Soft/Life/Self Skills – Self and SWOT Analysis ***and***

1. **Exercises on Productivity Development**
   - Effective/ Assertive Communication Skills (Activity based)
   - Time Management (Case Study)
   - Creativity & Critical Thinking (Case Study)
   - Decision Making and Problem Solving (Case Study)
   - Stress Management (Case Study)
2. **Exercises on Personality Development Skills**
   - Self-esteem (Case Study)
   - Positive Thinking (Case Study)
   - Emotional Intelligence (Case Study)
   - Team building and Leadership Skills (Case Study)
   - Conflict Management (Case Study)
3. **Exercises on Presentation Skills**
   - Netiquette
   - Importance of Oral Presentation – Defining Purpose- Analyzing the audience- Planning Outline and Preparing the Presentation- Individual & Group Presentation- Graphical Organizers- Tools and Multi-media Visuals
   - One Minute Presentations (Warming up)
   - PPT on Project Work- Understanding the Nuances of Delivery- Body Language – Closing and Handling Questions – Rubrics for Individual Evaluation (Practice Sessions)
4. **Exercises on Professional Etiquette and Communication**
   - Role-Play and Simulation- Introducing oneself and others, Greetings, Apologies, Requests, Agreement & Disagreement….etc.

- Telephone Etiquette
- Active Listening
- Group Discussions (Case study)- Group Discussion as a part of Selection Procedure- Checklist of GDs
- Analysis of Selected Interviews (Objectives of Interview)
- Mock-Interviews (Practice Sessions)
- Job Application and Preparing Resume
- Process Writing (Technical Vocabulary) – Writing a Project Report- Assignments

5. Exercises on Ethics and Values

Introduction –– Types of Values - Personal, Social and Cultural Values - Importance of Values in Various Contexts

- Significance of Modern and Professional Etiquette – Etiquette (Formal and Informal Situations with Examples)
- Attitude, Good Manners and Work Culture (Live Examples)
- Social Skills - Dealing with the Challenged (Live Examples)
- Professional Responsibility – Adaptability (Live Examples)
- Corporate Expectations

☞ Note: Hand-outs are to be prepared and given to students.

☞ Training plan will be integrated in the syllabus.

☞ Topics mentioned in the syllabus are activity-based.

SUGGESTED SOFTWARE:

☞ The following software from **'train2success.com'**

- Preparing for being Interviewed
- Positive Thinking
- Interviewing Skills
- Telephone Skills
- Time Management
- Team Building
- Decision making

SUGGESTED READING:

1. Alex, K. 2012. *Soft Skills.* S. Chand Publishers
2. *Management Shapers*. 2011. Collection of 28 Books by different Authors. Universities Press.
3. Sherfield, Robert M. *2005. et al Cornerstone: Developing Soft Skills*. Pearson
4. Suresh Kumar,E; Sreehari, P. & Savithri, J. 2011. *Communication Skills and Soft Skills- An Integrated Approach.* New Delhi: Pearson
5. The ACE of Soft Skills by Gopalaswamy Ramesh & Mahadevan Ramesh. 2013. Pearson Publishers. New Delhi.
6. Patnaik, P. 2011. *Group Discussion and Interview Skills.* New Delhi: Foundation
7. Sudhir Andrews. 2009. *How to Succeed at Interviews.* New Delhi: Tata McGraw Hill
8. **Sasikumar, V & Dhamija, P.V. 1993. *Spoken English - A Self-Learning Guide to Conversation Practice.* New Delhi: Tata McGraw-Hill**
9. *Dixson, Richard J. Everyday Dialogues in English. Prentice Hall India Pvt Ltd*
10. Mukhopadhyay. L *et al. 2012. Polyskills. New Delhi: CUP India Pvt Ltd*
11. Rizvi, M. A. 2005. *Effective Technical Communication.* New Delhi: Tata McGraw Hill
12. *The Hindu Speaks on Education* by the Hindu Newspaper
13. Naterop, B. Jean and Revell, Rod. 2004. *Telephoning in English*. Cambridge: CUP

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ES – 201 ENERGY MANAGEMENT AND CONSERVATION

OBJECTIVE:

- ✓ To get exposure to energy management of thermal and electrical systems and to understand the various conservation techniques.

OUTCOME:

Students get

- An exposure to Energy Consumption pattern resulting in energy savings and conservation.

Part A: Energy Management of Thermal Systems

1. **Energy Conservation:** Introduction - Indian Energy Conservation Act - List of Energy Intensive Industries - Rules for Efficient Energy Conservation - Identification of Energy Conservation opportunities - Technologies for Energy Conservation - Energy Conservation Schemes and Measures - Energy flow net works - Critical assessment of energy use - Optimizing Energy Inputs and Energy Balance - Pinch Technology.

2. **Energy Efficiency Improvement:** Steam Generation - Distribution and Utilization – Furnaces - Fans and Blowers - Compressors Pumps - Pinch Technology - Fluidized bed Combustion - Heat Exchanger Net works - Case Studies - Analysis and recommendation.

Part B: Energy Management of Electrical Systems

3. **AC Motors:** Squirrel Cage motors - Speed - Torque characteristics - Voltage imbalance – overloading of motor - Slip ring induction motor characteristics - Equivalent circuit - Single Phase Induction Motors **-** Starting & running performance - Split phase - Capacitor type motors - Characteristics - Reluctance motors – Universal motors – Stepper motor – Servo motor – Characteristics – Factors affecting efficiency.

4. **Energy Efficient Lighting**: Terminology - Laws of illumination - Types of lamps - Characteristics - Design of illumination systems - Good lighting practice - Lighting control - Steps for lighting energy conservation.

5. **Economics of Generation and Distribution:**
   Generation: Definitions - Connected load, Maximum demand - Demand factor – Diversity factor – Significance - Power Factor – Causes and disadvantages of low power factor – Economics of power factor improvement.
   Distribution: Electrical load analysis - Types of consumers & tariffs - Line losses - Corona losses - Types of distribution system - Kelvin's law - Loss load factor – Green Labeling – Star Rating.
   Utilization of Electric Drives: Selection of motors - Types of loads – Determination of RMS rating - Energy Consumption during starting of A.C and D.C motors - Braking of D.C and A.C motors - Plugging - Regenerative braking.

References Books:

a. Energy Conservation, Paul O' Callaghan, 1981.
b. Energy Management And Conservation , K V Sharma and P Venkataseshaiah
c. Energy Management/ Paul O' Callaghan, Mc Graw Hill, 1992
d. Energy Management Principles, Craig B. Smith, Pergamon Press
e. Electrical Machines, Bimbra, Khanna Publishers
f. Generation, Distribution & Utilization of Electrical Energy, CL Wadhwa, Wiley Eastern Ltd.
g. Electrical Machines, S.K.Bhattacharya
h. Electrical Machines, I.J.Nagarath and D.P.Kothari, TMH
i. Energy Efficient Electrical motors, John C. Andreas, Marcel Dekker Inc.
j. Energy Management and good lighting practice: Fuel Efficiency Booklet 12 / EEO.

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ES – 202 PHOTOVOLTAIC AND SOLAR THERMAL SYSTEMS

OBJECTIVES:

- To have a knowledge of solar power generation from PV panels and thermal systems.
- To get an exposure to different cell technologies.

OUTCOME:

Students get

- ✓ An exposure to advanced cell technology and usage of different materials.

1. **Solar Radiation and Measurements:** Solar radiation – Breakdown of incoming solar radiation, Energy Balance - Earth sun-angles-Types of Radiation – Measurements - solar Charts -Empirical equations for predicting the availability of solar radiation – Computation of radiation on inclined surfaces - Solar radiation data – Solar Tracking Systems – Single axis – Dual axis.

2. **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.

3. **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 (Organic PV, Heterojunction with intrinsic thin film – HIT - Quantum dots - Dye Sensitized Solar cell - Peroskvite solar cells etc).

4. **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 - Stand alone 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) - Use of PVSyst and PVSol software for design of solar PV power plants.

5. **Solar Thermal Systems and Applications:** Solar Flat plate collectors - Concentrating Collectors - Compound Parabolic Collector - Collector Efficiency - Solar water heating Systems - Solar Cookers - Solar Dryers and Industrial Process heating - Concentrated Solar Power (CSP) plants.

Reference Books:

a. Generating Electricity from the Sun/Edited by Fred C. Treble/Pergamon Press
b. Solar photovoltaics-Fundamentals ,technologies and Applications/Chetan Singh Solanki/PHI Learning private Ltd. New Delhi
c. Terrestrial Solar photovoltaics, Tapan Bhattacharya, Narosa Publishing House
d. Solar Electricity, Tomas Markvart, John Wiley and Sons
e. Solar Cells – Operating Principles, Technology and System Applications, Martin A. Green, Prentice Hall Inc
f. Modelling Photovoltaic Systems using P Spice, Luis Castaner and Santiago Silvestre, John Wiley and Sons
g. Solar Energy – Fundamentals and Applications, H.P. Garg and J. Prakash, Tata McGraw-Hill
h. Amorphous Silicon Solar Cells, K.Takahashi and M.Konagai, North Oxford Academic
i. Photovoltaic Systems Engineering, Roger Messenger, CRC Press

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ES – 202 DESIGN AND OPTIMIZATION OF ENERGY SYSTEMS (Elective-5)

OBJECTIVES:

- To have a knowledge of Optimization of Design Parameters.
- To have an exposure to different Design Methodologies and simulation processes.

OUTCOME:

Students have an exposure to

- Numerical Calculations
- Role of design parameters.
- Exposure to AI techniques like fuzzy logic & neural Network.

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

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

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 Optimisation Methods - Lagrangian multiplier – Application to thermal and electrical systems.

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

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

Reference Books:

a. Design and Optimization of Thermal Systems / Yogesh Jaluria / McGraw Hill
b. Optimization theory and applications / S.S.Rao / New Age Publication
c. Design of Thermal System / W.F.Stoecker / McGraw Hill
d. Operation Research / Panner Selvam / Prentice Hall
e. Optimization Research / M.C.Joshi
f. Simulation Modeling & Analysis / Law & Kelto
g. Operation Research / S Prinsc Valle Kasur

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ES – 204 ENERGY SCENARIO AND ENERGY POLICY
(Elective-5)

OBJECTIVE:
- To get an awareness of present energy pattern and to understand the energy policy.

OUTCOME:
Students have
- An exposure to Evaluation / utilization of energy usage and finding alternate energy resources and policy implications.

1. **Global Energy Scenario**: Role of energy in economic development and social transformation - Energy and GDP - GNP and its dynamics - Energy sources and overall Energy demand and availability - Energy consumption in various sectors and its changing pattern - Depletion of energy sources and impact exponential rise in energy consumption on economies of countries

2. **Energy Policies:** International Energy Polices of G-8 Countries - G-20 Countries - OPEC Countries - EU Countries - International Energy Treaties (Rio, Montreal, Kyoto) - INDO-US Nuclear Deal.

3. **Indian Energy Scenario:** Energy resources and Sector wise energy Consumption pattern Impact of energy on economy and development - National and State Level Energy polices and Issues - Status of Nuclear and Renewable Energy and Power Sector reforms.

4. **Energy Policy:** Global Energy Issues - Energy Security - Energy Vision Energy Pricing and Impact of Global Variations Energy Productivity (National and Sector wise productivity).

5. **Energy Conservation**: Act – 2001 and its features - Electricity Act – 2003 and its features - Energy Crisis - Future energy options - Need for use of new and renewable energy sources - Energy for Sustainable development.

Reference Books:
a. Energy for a sustainable World: Jose Golden berg, Thomas Johan son, AKN. Reddy, Robert Williams (Wiley Eastern).
b. Energy Policy, B.V. Desai (Wiley Eastern)
c. Modeling approach to long term demand and energy implication, J.K.Parikh
d. Energy Policy and Planning, B.Bukhootsow
e. TEDDY Year Book Published by Tata Energy Research Institute(TERI) World Energy Resources, Charles E. Brown, 'International Energy Outlook' - EIA annual Publication
f. BEE Reference book: no. 1/2/3/4

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ES – 205 CO-GENERATION AND HYBRID VEHICLES
(Elective-5)

OBJECTIVES:
- To impart knowledge on Energy savings by studying.
- To have an exposure about Hybrid Electric Vehicles.

OUTCOME:
Students get
- The knowledge on generation of energy with different methods.

1. **Concept of Cogeneration**: Review on Thermodynamics of conventional power producing plants - Selecting cogeneration technologies.

2. **Thermodynamics of Cogeneration Power Plants:** Performance criteria and effect of irreversibility - Comparative thermodynamic performance of cogeneration plants – Numerical examples – Calculations of typical heat to power ratios and performance parameters.

3. **Design of CHP:** Design of Cogeneration plant for varying plant heat to power ratio – Fuel savings from installation of cogeneration plant - Applications of cogeneration technology to various process plants.

4. **Introduction to Hybrid Electric Vehicles:** History of hybrid and electric vehicles - Social and environmental importance of hybrid and electric vehicles - Impact of modern drive-trains on energy supplies.

5. **Hybrid Electric Drive-trains:** Basic concept of hybrid traction - Introduction to various hybrid drive-train topologies - Power flow control in hybrid drive-train topologies - Fuel efficiency analysis.

Reference books:
a. Cogeneration Combined Heat and Power – Thermodynamics and Performance, Horlock, J. H., Pergamon Press, 1986.
b. Cogeneration, David Hu, S., Reston Publishing Co., USA, 1985.
c. Combined Production of Heat and Power, Sirchis, J., Elsevier Applied Science, 1990.
d. Cogeneration of Steam and Electric Power, Robert Noyes, Noyes Data Corporation, 1986.
e. Cogeneration, Spiewak, S. A., Fairmont Press Inc., 1991.
f. Combined Cycle Gas and Steam Turbine Power Plants, Kehlhofer, R., The Fairmont Press Inc., 1991.

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ES – 206 NUCLEAR ENERGY AND ITS APPLICATIONS
(Elective-6)

OBJECTIVE:

- To understand the concept and different technologies in energy generation, their advantages.

OUTCOME:

- Support to convention energy sources in energy crisis and its utilization extent and particularly nuclear energy risk management

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.

2. **Nuclear Reactors:** General components of nuclear reactor - Fuel cladding - fuel assembly – moderators – coolants - control rods -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 - Reactor safety - Neutron Population growth - Assurance of safety - Emergency core cooling and containment.

3. **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.

4. **Biological and Environmental Effects:** Biological effects of radiation - Radiation dose - Basic for limits and exposure - Sources of radiation dosage - Gas counters - Neutron detectors - Scintillation counters - Solid state detectors - Statistics of counting - Pulse height analysis - Protective measures - Calculation of dose - Effects of distance and shielding - Internal exposure - The Radon problem - Environmental radiological impact - Radiation standards.

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.

Reference Books:

a. Nuclear Power Technology, W.Marshall, Vol. I &II, Clarendon press, Oxford, 1985.
b. Principle of Nuclear Reactor Engineering, Samual Glasstone, Van Nostrand Reinhold Co. Inc., New York, 1963.
c. Nuclear Power Station, Margulova, Mir Publishers, Moscow, 1978.
d. Principle of Energy Conversion, Archie W.Culp, McGraw Hill Kogakusha Ltd., 1984.
e. A Course in Power Plant Technology, Domkundwar, Dhanpat Rai Sons

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ES – 207 SOLAR REFRIGERATION AND AIR-CONDITIONING
(Elective-6)

OBJECTIVE:
- To have awareness of Solar applications to Solar refrigeration and air-conditioning.

OUTCOMES:
Students get
- To make, design modifications and cost reduction methods.
- An exposure on Solar refrigeration or A/C.

1. **Concept of Solar Energy**: Review of Solar Collectors - Solar concentrators - Potential and scope of solar cooling - Types of solar cooling systems - Solar collectors and storage systems for solar refrigeration and air-conditioning.

2 **Solar operation of vapor absorption and vapor compression:** A refrigeration cycles and their thermodynamic assessment - Rankine cycle - Sterling cycle based on solar cooling systems - Fuel assisted solar cooling systems.

3 **Solar desiccant cooling systems**: Open cycle absorption – Desorption of solar cooling alternatives - Advanced solar cooling systems.

4 **Thermal modeling**: Computer simulation for continuous and intermittent - Solar refrigeration and air-conditioning systems - Refrigerant storage for solar absorption cooling systems.

5 **Solar thermoelectric refrigeration and air-conditioning**: Solar thermo acoustic cooling and hybrid air-conditioning - Solar economics of cooling systems.

Reference Books:
a. A course in Refrigeration and Air- conditioning, S. Domakundwar and S.C Arora,
b. Principles of Solar Engineering, F.Kreith and J.F Kreider,
c. Solar cooling and Heating Volumes, T. Nejat Vezirogulu, I, II & III.
d. Solar air conditioning and refrigeration, A. A. M. Sayigh, J. C. McVeigh

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ES – 208 HYDROGEN AND FUEL CELLS
(Elective-6)

OBJECTIVE :

- To introduce to emerging technologies like production and storage of Hydrogen

OUTCOME:

Students gets

- Exposure to different fuel cells in particularly Hydrogen fuel cells

1. **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.

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.

3. **Hydrogen Storage & Transport:** Hydrogen storage options – Compressed gas – Liquid hydrogen – Hydride – Chemical Storage – Comparisons - Transport of Hydrogen - Pipelines, gaseous, liquid and compound materials.

4. **Fuel Cells:** History – Principle - Working - Thermodynamics and kinetics of fuel cell process – Performance evaluation of fuel cell – Comparison on battery Vs fuel cell - Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC – Relative merits and demerits.

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.

Reference Books:

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

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ES – 209 ADVANCED CONTROL SYSTEMS
(Elective-7)

OBJECTIVES:

- To design a linear system and obtain controllability and observability.
- To study about non linear systems and also to obtain stability analysis.
- To get an exposure to optimization techniques.

OUTCOMES:

Students gets

- ✓ An exposure to advanced control techniques both for linear as well as non linear systems.
- ✓ An exposure to optimization techniques applicable to control systems.

1. **Classical Design Techniques For Linear Control Systems:** Lag - Lead & Lag-Lead Compensation - State Space Analysis - State Space Representation - State Models - Solution of State Equation - State Transition Matrix - Canonical Forms - Controllable Canonical Form - Observable Canonical Form - Jordan Canonical Form.

2. **Controllability and Observability:** Tests for Controllability and Observability for Continuous Time Systems - Time Varying Case - Minimum Energy Control - Time Invariant Case - Principle of Duality - Controllability and Observability for Jordan Canonical Form and other Canonical Forms.

3. **Describing Function Analysis:** Introduction to nonlinear systems - Types of nonlinearities - describing functions - Describing function analysis of nonlinear control systems - Phase-Plane Analysis - Introduction to phase-plane analysis - Method of Isoclines for Constructing Trajectories - Singular points.

4. **Stability Analysis:** Stability in the sense of Lyapunov - Lyapunov's stability and Lyapanov's instability theorems - Direct method of Lyapunov for the Linear and Nonlinear continuous Time Autonomous Systems - Model Control - Effect of state feedback on controllability and observability - Design of State Feedback Controllers through Pole Placement - Full Order Observer & Reduced Order Observer.

5. **Calculus of Variation:** Minimization of Functional of Single Function - Constrained minimization - Minimum principle - Control Variable Inequality Constraints - Control and State Variable Inequality Constraints - Euler Lagrangine Equation - Introduction to Optimal Control - Formulation of Optimal Control Problem. Minimum Time - Minimum Energy - State Regulator Problem.

Reference Books:

a. Modern Control System Theory- by M. Gopal, New Age International Publishers, 2nd edition, 1996
b. Modern Control Engineering - by K. Ogata, Prentice Hall of India, *3rd* edition, 1998
c. Control Systems Engineering by I.J. Nagarath and M.Gopal, New Age International (P) Ltd.
d. Digital Control and State Variable Methods - by M. Gopal, Tata Mc Graw-Hill Companies, 1997.
e. Systems and Control by Stainslaw. H. Zak, Oxford Press, 2003.
f. Modern control System - By Dorf, Pearson

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ES – 210 INDUSTRIAL WASTE MANAGEMENT AND RECYLING (Elective-7)

Objectives:

- ✓ To make the students realize the importance of treatment, Disposal and energy recovery of waste from various industries including agriculture through the knowledge of processes, Equipment and Materials used in industrial waste – Characteristics & Composition of industrial waste and the pollution control techniques.

Outcomes:

- ✓ Students shall be able to Categorize the waste from various industries & recycle for energy extraction.

Unit-I: 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.

Unit-II: 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-III: Sources of Effluent from the Process of Industries:

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-IV: 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-V: 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.

Reference Books:

1. Hand book of solid waste management and Waste Minimization Technologies Nicholas P. Chermissionoff. An imprint of Elsevier, New Delhi (2003).
2. Solid Waste Engineering, P. Aarne Vesilind, William A. Worrell and Debra R. Reinhart. Thomason Asia Pvt. Ltd. Singapore (2002).
3. 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).
4. Design, Construction and Monitoring of Landfills, Amalendu Bagchi.John Wiley and Sons. New York. (1994).
5. Environmental Pollution Control Engineering, C.S.Rao Wiley Eastern Ltd. New Delhi (1995).
6. Industrial Waste Water Pollution Control, W. Wesley Eckenfelder Jr., McGraw- Hill, 2000.
7. 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.
8. Treatment of Industrial Effluent, Callegy, Forster and Stafferd, Hodder and Stonghton 1988.

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ES – 211 INTEGRATION OF RENEWABLE ENERGY SOURCES (Elective-7)

Objectives:

Upon successful completion of the course the students will be familiar with:

- ✓ To introduce the characteristics of various types of renewable energy sources and converters.
- ✓ To explain the importance of storage and sizing of hybrid systems.
- ✓ To introduce the control issues of isolated systems.
- ✓ To explain the harmonics, power quality, voltage imperfections, power injection issues on the grid by integrating renewable energy sources.

Outcomes:

At the end of the course, the student should be able to:

- ✓ Identify the characteristics of renewable energy sources and converters.
- ✓ Analyze the importance of storage and sizing of hybrid systems.
- ✓ Realize the problems related to isolated systems.
- ✓ Analyze the challenges faced by the grid by integrating renewable energy sources.

1. **Review Of Characteristics Of Power Sources:** Basic review of power generation from wind - Solar PV - Thermal - Small hydro - Biomass power strategies in each of these energy conversion systems - Review of maximum power point tracking techniques in solar PV and wind (perturb & observe, hill climbs, incremental conductance).

2. **Converter Topologies:** DC/DC converter (buck, boost, buck boost) - DC/AC inverters (sine, triangular, PWM techniques) - Phase locked loop for inverters.

3. **Hybrid Systems:** Advantages of hybrid power systems - Importance of storage in hybrid power systems - Design of hybrid power system based on load curve - Sizing of hybrid power systems.

4. **Isolated Systems:** Control issues in isolated systems for voltage and frequency - Small signal stability in isolated power systems - Importance of storage and dump load in isolated systems.

5. **Issues In Integration Of Renewable Energy Sources:** Overview of challenges in integrating renewable sources to the grid - Impact of harmonics on power quality - 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 - Challenges in modeling intermittent nature of renewable power in a power system.

References Books:

a. Power Electronics, Converters, Applications and Design" by N. Mohan; T.M. Undeland; W.P. Robbins. 1995, John Wiley and Sons.
b. Renewable Energy IntegrationChallenges and SolutionsSeries: Green Energy and Technology**Hossain**, Jahangir, Mahmud**,** Apel (Eds.)
c. Integration of Alternative Sources of EnergyFelix A. Farret**,** M. Godoy Simões December 2005, Wiley-IEEE Press.

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ES – 212 BIO CONVERSION AND PROCESSING OF WASTE
(Elective-8)

OBJECTIVE:

- ✓ To inculcate knowledge on bio technologies and processing of wastes.

OUTCOME:

- ✓ Energy Conservation opportunities on recovery systems and to develop new technologies.

1. **Biomass Resources And Biomass Properties:** Biomass – Definition – Classification – Availability – Estimation of availability - Consumption and surplus biomass – Energy plantations Proximate analysis - Ultimate analysis - Thermo gravimetric analysis - Summative analysis of biomass – Briquetting.

2. **Biomass Pyrolysis:** Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods - Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.

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.

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.

5. **Introduction to Energy from Waste:** Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors

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.

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ES – 213 POLLUTION CONTROL IN POWER PLANTS

OBJECTIVE:

- ✓ To make aware and understand of the subject and its impact on power plants.

OUTCOME:

Students are exposed to

- ✓ Minimization / elimination/ introduction of new technologies, identify optimum energy utilization techniques.

1. **Coal Power Plants:** CO_2 mitigation - Carbon foot-print reduction - Carbon credits - Fly Ash generation and environment impact - Fly ash utilization and disposal.

2. **Fluidized Bed Boilers:** Post Combustion Controls, Particulate controls, Cyclone, Wet scrubbers, ESP and fabric filters.

3. **Nuclear Power Plants:** Nuclear fuel cycle, Radioactive wastes – treatment and disposal.

4. **Pollution Control Methods:** Pre-combustion controls - Combustion controls Low NOx burners, Clean Development Mechanism (CDM).

5. **Gaseous pollutants controls:** flue gas desulfurization (FGD) systems, CSR reduction applications of electron beam and non thermal plasmas for SOx and NOx treatments, Thermal pollution and its impact on aquatic life.

Reference Books:

a. Introduction to Environmental Engineering and Science, M. Giblbert Masters. Prentice Hall, 1991
b. Environmental Pollution Control Engineering. C. S. Rao. Wiley Eastern Ltd. Delhi 1991
c. Estimation of resource savings due to fly ash utilization in road construction. Resource conservation and Recycling, Subodh Kumar and C. B. Patil. 48, 125-140 (2006)
d. Potential of fly ash utilization in India. U. Bhattcharjee and T. C. Kandpal. Energy 27, 151-66, 2002.
e. TIFAC (Technology Information Forecasting and assessment Council) Home page http://www.tifac.org.in/news/flyindia.htm.2005
f. Nuclear engineering handbook. H. Etherington. McGraw Hill (New York) 1958
g. Power Plant Engineering, P. K. Nag, Tata McGraw Hill (2001)
h. Fuel and Combustion . Samir Sarkar., Orient Longman Limited. (Hydrabad), 2001.
i. Power Plant Technology, El Wakil, Mc Graw Hill

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ES – 214 COMPUTATIONAL FLUID DYNAMICS

OBJECTIVE:

The course is intended to

- Impart the advances knowledge of heat transfer
- Get analytical solutions for 2-D steady and transient heat conduction problems.
- Deep understanding on the governing equations for convection heat transfer; knowing the dimensionless parameters (influencing the convection performance).
- Aware of turbulence concept and modeling.
- Apply the concept of natural convection for electronic cooling, HVAC etc.
- Understand the boiling and condensation mechanism.
- Understand the concept of mass transfer**.**

OUTCOME:

At the end of the course, the student will be able to:

- Understand both the physics and the mathematical treatment of the advanced topics pertaining to the modes of heat transfer.
- Apply principles of heat transfer to develop mathematical models for uniform and Non-uniform fins.
- Employ mathematical functions and heat conduction charts in tackling two
- Dimensional and three-dimensional heat conduction problems.
- Analyze free and forced convection problems involving complex geometries with proper boundary conditions.
- Apply the concepts of radiation heat transfer for enclosure analysis.
- Understand physical and mathematical aspects of mass transfer.

1. **Introduction to Numerical Methods:** Finite Difference, Finite Element and Finite Volume Methods – Classification of Partial Differential Equations – Solution of Linear Algebraic Equations – Direct and Iterative Approaches
   Finite difference methods:- Taylor's series – FDE formulation for 1D and 2D steady state heat transfer problems – Cartesian, cylindrical and spherical co-ordinate systems – Boundary conditions – Un steady state heat conduction – Errors associated with FDE - Explicit Method – Stability criteria – Implicit Method – Crank Nickolson method – 2-D FDE formulation – ADI – ADE
2. **Finite Volume Method (FVM)**: Formation of Basic rules for control volume approach using 1D - steady heat conduction equation – Interface Thermal Conductivity - Extension of General Nodal Equation to 2D and 3D Steady heat conduction and unsteady heat conduction
3. **FVM to Convection and Diffusion:** Concept of Elliptic, Parabolic and Hyperbolic Equations applied to fluid flow – Governing Equations of Flow and Heat transfer – Steady 1DConvection Diffusion – Discretization Schemes and their assessment – Treatment of Boundary Conditions

4. **Calculation of Flow Field :** Vorticity & Stream Function Method - Staggered Grid as Remedy for representation of Flow Field - Pressure and Velocity Corrections – Pressure Velocity Coupling - SIMPLE & SIMPLER (revised algorithm) Algorithm.
5. **Grid generation:** Algebriac methods, differential equation methods.

Reference Books:

a. Numerical heat transfer and fluid flow – S.V. Patankar (Hemisphere Pub. House)
b. An Introduction to Computational Fluid Dynamics – FVM Method – H.K. Versteeg, W. Malalasekhara (PHI).
c. Computational Fluid Flow and Heat Transfer – Muralidharan & Sundarajan (Narosa Pub)
d. Computational Fluid Dynamics – Hoffman and Chiang, Engg Education System
e. Computational Fluid Dynamics – Anderson (TMH)
f. Computational Methods for Fluid Dynamics – Ferziger, Peric (Springer)
g. Computational Fluid Dynamics, T.J. Chung, Cambridge University
h. Computaional Fluid Dynamics – A Practical Approach – Tu, Yeoh, Liu (Elsevier)
i. Text Book of Fluid Dynamics, Frank Chorlton, CBS Publishers

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ES – 215 SMART GRID TECHNOLOGIES

OBJECTIVE:

- To understand concept of smart grid and developments on smart grid.
- 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.

Outcomes:

After completion of the course, students are able to:

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

Unit-I : 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-II : Smart Grid Technologies: 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 – III: Smart Grid Technologies : Smart Substations – Substation automation – Feeder automation – Intelligent electronic devices(IED) & their application for monitoring 7 protection – Smart storage like battery – SMES- Pumped hydro – Compressed air energy storage – Wide area measurement system(WAMS)-Phasor measurement unit(PMU).

Unit –IV : 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.

Unit – V: Information and Communication Technology for Smart Grid: Advanced metering infrastructure (AMI)- Home area network (HAN)- Neighborhood area network(NAN)-Wide area network(WAN).

Reference Books:

1. "Integration of Green and Renewable Enegry 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", JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, 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.
8. "The Advanced Smart Grid: Edge Power DrivingSustainability: 1", Andres Carvallo,John Cooper ,Artech House Publisher July 2011.
9. "Control and Automation of Electric power Distribution Systems (Power Engineering)',James Northcote, Green, Robert G. Wilson CRC Press.
10. "Substation Automation (Power Electronics and Power Systems)", MladenKezunovic, Mark G.Adamiak, Alexander P. Apostolov, Jeffrey Georg
11. Gilbert Springer."Electrcial Power System Quality",R.C.Durgan, Mark F. McGranghan, Surya Santoso, H. Wayne Beaty,2ND Edition , McGraw Hill Publication.
12. Communication and Networking in Smart Grids", Yang Xiao, CRC Press.

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ES – 207 ENERGY SYSTEM LABAROTARY

Study of

a. Operational experience on i) Pyranometer, ii) Sunshine recorder
b. Measurement of speed using Tachometer, Stroboscope and anemometers
c. Measurement of temperature using Infrared Thermometers
d. Measurement of illumination using Lux meter
e. Exhaust gas analysis using gas analyzer

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 Concentrating water heating system
4. Determination of conversion efficiency of a solar air heating system
5. Study and analysis of a solar still / distillation plant
6. Performance estimation of photovoltaic water pumping system
7. Investigation on a solar dryer
8. Operational characteristics of P.V. Indoor lighting system
9. Determination of characteristics of a wind generator
10. Performance evaluation of solar cooker
11. P.V. System sizing exercise
12. Data acquisition system for continuous monitoring of P.V system parameters using LABVIEW software
13. Performance estimation of Solar fuel cell
14. Performance evaluation of vertical and horizontal axes wind turbine rotors.

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Project Phase – I & II and Dissertation

Outcomes:

At the end of the course the student will be able to

- Identify the problem of a research project through literature survey.
- Analyze the technical feasibility of the project.
- Propose the solution for the research problem.
- Analyze and design the proposed solution using Simulation Tools