M.Tech. - Renewable Energy

Course Duration:

2 Years– 4 Semesters

Eligibility Criteria:

- ✓ A candidate with 4 years Bachelor's Degree in Technical Programme in appropriate Domain with NCRF/UCF level 6.0 completed with a minimum of 55% marks or CGPA of 5.5 on a 10-point scale in the qualifying examination(50% marks or CGPA of 5.0 on a 10-point scale for SC/ST candidates) from UGC / AICTE recognized Institute / University.

The selection will be as per Gandhigram Rural Institute Norms.

Category A

Based on the GATE Score.

Category B

Based on the Common University Entrance Test (CUET) Examination

Maximum number of Seats: 20

Programme Educational Objectives (PEOs):

To prepare the students to be successful professional in the field of Renewable Energy

1. To strengthen their knowledge and analytical skill to improve the Renewable Energy System Performance
2. To make the students understand, analyze, design, and create products / process to solve the renewable energy related issues.
3. To prepare the students to pursue research in latest technologies in Renewable Energy
4. To train the students to use Renewable Energy technologies for sustainable rural development
5. To inculcate professional ethics, effective communication skills, sprit of teamwork and ability to conduct energy analysis of various systems.

Programme Outcome

1. Demonstrate knowledge of mathematics, science and engineering in the field of Renewable Energy
2. Acquire knowledge in re-engineering of Renewable energy system for enhancing the efficiency
3. Enhance the skill to troubleshoot the renewable energy gadgets and analyze their performance
4. Quantify the Carbon emission reduction process through energy auditing and renewable energy integration
5. Apply modern software tools and techniques to optimize the performance of renewable energy systems
6. Observe and analyze energy related issues in rural areas for arriving sustainable solution considering Energy, Efficiency, Environment and Economics aspects including Governmental Polices
7. Appreciate the impact of renewable energy solution for societal improvement
8. Will develop confidence for self-education, community living and ability for life-long learning
9. Design a Product / Process on Renewable Energy / Energy Efficiency and Prepare a Comprehensive report

Programme Specific Outcome

1. Apply the knowledge of Renewable Energy in solving energy related problems being faced in society / industry
2. Solve the complex problems in the field of Renewable Energy with an understanding of Societal, legal and environmental impact of the solution
3. Design and Development of Cost Effective Renewable Energy Technologies
4. Apply the knowledge to develop Detailed Project Report for Rural Energy Planning
5. Demonstrate and Disseminate the knowledge in Renewable Energy for integrating energy efficiency and enhancement

PEO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	3	2	3	3	3	2	3	3	3	3	1	3
2	3	3	-	2	3	2	2	1	3	3	3	3	3	2
3	2	3	3	3	3	3	2	-	3	3	3	3	3	3
4	3	3	2	2	3	3	3	-	3	3	3	2	3	3
5	1	3	3	3	3	3	3	2	3	3	2	2	3	3
6	1	3	3	3	2	3	3	3	3	3	3	3	3	2

M.Tech RENEWABLE ENERGY

Type	Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
							CFA	ESE	Total
Semester I									
Core I	24REPC1101	Solar Energy Utilization	4	4	0	0	40	60	100
Core II	24REPC1102	Wind, Hydro & New Energy Horizons	4	4	0	0	40	60	100
Elective I	24REPD110X	Electives- Discipline Centric-1	3	4	0	0	40	60	100
Elective II	24REPD110Y	Electives- Discipline Centric-2	3	4	0	0	40	60	100
Core	24REPC1103	Solar Energy Laboratory	3	0	0	4	60	40	100
Core	24REPC1104	Wind Energy Laboratory	3	0	0	4	60	40	100
Core	24REPC1105	Research Methodology and IPR	4	4	0	0	40	60	100
Audit Course I	24GTPP001	Gandhi in Every Day Life	2	2	0	0	50	0	50
		Total	**26**	**22**	**0**	**8**	**370**	**380**	**750**
Semester II									
Core III	24REPC1201	Renewable Integrated Power Systems	4	4	0	0	40	60	100
Core IV	24REPC1202	Waste to Energy	4	4	0	0	40	60	100
Elective III	24REPD120X	Electives- Discipline Centric-3	3	4	0	0	40	60	100
Open Elective		Electives- Generic	3	4	0	0	40	60	100
Core	24REPC1203	Waste to Energy Laboratory	3	0	0	4	60	40	100
Field Visit	24REPE1201	Energy Auditing of MSMEs (Field Visit)	2	0	0	4	30	20	50
Core	24REPC1204	Simulation & Analysis of Renewable Energy Sources and Devices Laboratory	3	0	0	4	0	50	50
Core	24REPC1205	Universal Human Values and Professional Ethics	2	0	0	4	50	0	50
Audit Course II	24ENGP00C1	Communication & Soft Skills	2	2	0	0	50	0	50
Non-Credit Value-Added Course		Inter-Departmental Courses	-	2	0	0	50	0	50
		Total	**26**	**20**	**0**	**12**	**350**	**350**	**700**
Semester III									
Core	24REPC2101	Summer Internship	2	0	0	0	0	50	50
Elective IV	24REPD210X	Elective- Discipline Centric-4	3	4	0	0	40	60	100
Elective V	24REPD210Y	MOOC 1	2	2	0	0	50	0	50
Elective VI	24REPD210Z	MOOC 2	2	2	0	0	50	0	50

Field Visit	24REPE2101	Rural Energy Planning (Field Visit)	3	2	0	4	60	40	100
Modular Course	24REPM210X	Modular Course	2	2	0	0	50	0	50
Dissertation	24REPC2102	Dissertation I	8	0	0	20	150	50	200
Extension	24REPE2101	Village Placement Programme	2	0	0	0	50	0	50
Non-Credit Value-Added Course		Inter-Departmental Course	-	2	0	0	50	0	50
		Total	24	**10**	**0**	**24**	**400**	**200**	**600**
Semester IV									
Dissertation	24REPC2201	Dissertation II	**14**	**0**	**0**	**32**	**150**	**50**	**200**
			14						
		Total	**90**						

Courses for 24REPD110X

24REPD1101 Energy Auditing and Conservation
24REPD1102 Optimum Utilization of Heat and Power
24REPD1103 Thermodynamic Analysis of Energy Systems
24REPD1104 Instrumentation for Energy Systems

Courses for 24REPD110Y

24REPD1105 Advanced Numerical Analysis
24REPD1106 GHG Accounting and Sustainability Reporting
24REPD1107 Computational Fluid Dynamics
24REPD1108 Optimization Techniques for Sustainability

Courses for 24REPD120X

24REPD1201 Artificial Intelligence in Renewable Energy Technologies
24REPD1202 Energy Forecasting and Project Management
24REPD1203 Modeling and Analysis of Energy Systems
24REPD1204 Big Data Analytics for Renewable Energy System

Courses for 24REPD210X

24REPD2101 Green Hydrogen
24REPD2102 Rural Micro Grids
24REPD2103 Energy Efficient Buildings
24REPD2104 Electrical Vehicles and Energy Storage

Courses for 24REPM210X

24REPM2101 Solar PV Project Management
24REPM2102 Entrepreneurship in Green Hydrogen
24REPM2103 Wind Resource Assessment and Site Survey
24REPM2104 Waste Management

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPC1101	Solar Energy Utilization	4	4	0	0	40	60	100

Course Objectives:

CO1 : Describe the fundamentals of Solar Physics
CO2 : Design and analysis of the solar thermal devices
CO3 : Design and analysis of the solar Photo Voltaic System
CO4 : Understand the government schemes and policies on Solar Energy
CO5 : Study the application of Solar Energy for Societal needs

Cognitive Level

K1 : Identify various terminologies of Solar Systems
K2 : Evaluate the Solar Energy Potential
K3 : Calculate the optical and heat transfer efficiency of solar thermal / PV systems
K4 : Design the Solar Thermal Collectors & PV Systems
K5 : Performance Evaluation and Cost benefit analysis of Solar Systems

Unit I

Solar angles, day length, angle of incidence on tilted surface; Sunpath diagrams; Shadow determination; Extraterrestrial characteristics; Effect of earth atmosphere; Measurement & estimation on horizontal and tilted surfaces; Analysis of Indian solar radiation data and applications.

Flat-plate Collectors - Effective energy losses; Thermal analysis; Heat capacity effect; Testing methods; Evacuated tubular collectors; Air flat-plate Collectors: types; Thermal analysis; Thermal drying.

Selective Surfaces -Ideal coating characteristics; Types and applications; Anti-reflective coating; Preparation and characterization.

Unit II

Concentrating Collector Designs - Classification, Tracking systems; Compound parabolic concentrators; Parabolic trough concentrators; Concentrators with point focus; Heliostats; Comparison of various designs: Central receiver systems, parabolic trough systems; Solar power plant; Solar furnaces; Vapour absorption refrigeration cycle; Water, ammonia & lithium bromide-water absorption refrigeration systems; Solar operated refrigeration systems; Solar desiccant cooling. Solar Thermal Energy Storage - Sensible storage; Latent heat storage; Thermo-chemical storage. Solar still; solar cooker: Solar pond.

Unit III

Solar Passive Building - Thermal comfort; Criteria and various parameters; Calculation of solar radiation on buildings; building orientation; Introduction to design of shading devices; Overhangs; Factors that effects energy use in buildings; Ventilation and its significance; Air-conditioning systems; Passive Cooling And Heating Concepts - Passive heating concepts: Direct heat gain, indirect heat gain, isolated gain and sunspaces; Passive cooling concepts: Evaporative cooling, radiative cooling; Application of wind, water and earth for cooling; Shading, paints and cavity walls for cooling; Roof radiation traps; Earth air-tunnel.

Unit IV

Solar Cell Physics –P-N junction: homo and hetro junctions, Metal-semiconductor interface; Dark and illumination characteristics; Figure of merits of solar cell; Efficiency limits; Variation of efficiency with band-gap and temperature; Efficiency measurements; High efficiency cells,

Tandem structure.SPV Applications - Centralized and decentralized SPV systems; Standalone, hybrid, and, grid-connected system, System installation, operation, and maintenance

Unit V

SOLAR POWER PLANTS (PV): Schematic arrangement of PV plant, Off-grid and On-grid systems, Merits and limitations - Net metering, Estimation of Energy bill saving and carbon footprint, System Design, MPPT, DC/DC converters, DC/AC converters, Life cycle costing (LCC), Approach and Methodology to develop large Roof Top Plants, Business Models for large capacity rooftop PV plants, New solar cell technologies.

Text Book:

1. Garg H P., Prakash J., *Solar Energy: Fundamentals & Applications*, Tata McGraw Hill, New Delhi, 1997
2. S P Sukhatme, *Solar Energy*, Tata McGraw Hill, 2008
3. J F Kreider and Frank Kreith, *Solar Energy Handbook*, McGraw Hill, 2000

References:

1. D Y Goswami, Frank Kreith and J F Kreider,*Principles of Solar Engineering*, Taylor& Francis, 1998
2. Tiwari G.N., Suneja S., *Solar Thermal Engineering System*, Narosa Publishing House, New Delhi, 1997.
3. Alan L Fahrenbruch and Richard H Bube , *Fundamentals of Solar Cells: PV Solar Energy Conversion,*Academic Press, New York , 1983
4. Larry D Partain (ed.), *Solar Cells and their Applications,*John Wiley and Sons, Inc, New York, 1995
5. Richard H Bube, *Photovoltaic Materials*, ImperialCollege Press, 1998
6. H S Rauschenbach, *Solar Cell Array Design Handbook*, Van Nostrand Reinfold Company, New York, 1980.

Course Outcomes

At the end of the course learner will be able to

- ✓ Understand the physics of solar energy
- ✓ Evaluate the solar thermal devices.
- ✓ Optimize the solar thermal power generating system.
- ✓ Design the solar PV system for rural households.
- ✓ Interpret from field experience for solar PV market analysis including government schemes & policies.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	2	-	2	1	-	-	2	3	3	3	3	-	2
2	3	2	3	2	3	2	2	1	3	3	3	3	-	2
3	3	2	3	2	3	2	2	1	3	3	3	3	-	2
4	-	1	1	3	-	3	3	3	3	3	3	2	3	3
5	-	3	-	3	-	2	3	3	3	3	3	2	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPC1102	Wind, Hydro & New Energy Horizons	4	4	0	0	40	60	100

Course Objectives:

CO1 : Describe the fundamentals and main characteristics of wind energy conversion Techniques
CO2 : Analyze the potential of small hydro power generation
CO3 : Explore the possibility of usage of biofuel
CO4 : Study the fundamentals of new renewable energy technologies like fuel cell, Geothermal energy, Ocean energy etc.
CO5 : Study the application of New Renewable Energy for Societal needs

Cognitive Level

K1 : Identify various terminologies of Wind, Small hydro and new renewable energy Systems
K2 : Evaluate the New Renewable Energy Potential
K3 : Calculate the input / output relationship of wind, small hydro, OTEC & Fuel Cell
K4 : Design the Wind Turbine blades, Small Hydro Turbines and Fuel Cells
K5 : Performance Evaluation and Cost benefit analysis of New Renewable Energy System

Unit I

Wind Energy Conversion - Wind energy conversion principles; General introduction; Types and classification of WECS; Power, torque and speed characteristics. – Site Selection Criteria – Advantages – Limitations – Wind Rose Diagram – Indian Wind Energy Data – Organizations like NIWE etc., Wind Energy Conversion System - Design - Aerodynamic design principles; Aerodynamic theories; Axial momentum, blade element and combine theory; Rotor characteristics; Maximum power coefficient; Prandlt's tip loss correction.

Unit II

Design of Wind Turbine - Wind turbine design considerations; Methodology; Theoretical simulation of wind turbine characteristics; Test methods. Wind Energy Application - Wind pumps: Performance analysis, design concept and testing; Principle of WEG; Stand alone, grid connected and hybrid applications of WECS; Economics of wind energy utilization; Wind energy in India; Case studies.

Unit III

Small Hydropower Systems –Fluid Mechanics – equations of motion -Euler's equation along a streamline – Bernoulli's equation -Laminar flow between parallel plates – flow through circular pipe – friction factor – smooth and rough pipes – Moody diagram

Overview of micro, mini and small hydro systems; Hydrology; Elements of pumps and turbine; Selection and design criteria of pumps and turbines; Site selection and civil works

Speed and voltage regulation; Investment issues load management and tariff collection; Distribution and marketing issues: case studies; Potential of small hydro power in India. – SHP – Renovation and Modernization – Testing Methods

Unit IV

Bio fuels – Edible –Petro crops – Analysis of Indian non edible oil sources – Example of biodiesel crop – Jatropha curcas – Tree description – Jatropha curcas for rural development – environmental protection – Bio ethanol – production from conventional as well as unconventional sources. - Bio diesel – Technology for production of bio diesel - Transesterification – Process – Usage of Methanol – Glycerine – Storage and Characterization of biodiesel – Biodiesel engine development – modification – Environmental and health effects of biodiesel – R&D in biodiesel –disposal of cake – value addition of byproducts– Blending – Concept of Alternative Bio-CNG: Bio CNG production and Bottling for commercial value addition.

Unit V

Ocean Energy Potential - OTEC- International – National Scenario - Principles and Prospective Locations – Open – Closed Loop Cycle - Tidal Energy- Global Technological Development - Estimation of Tidal Power - Different Types of Turbine - Geothermal- Potential – Layout - MHD – Technology and Bottlenecks - Thermionic- Thermoelectric energy conversion system

Fuel Cells – Proton exchange membrane fuel cells (PEMFCs) - Phosphoric acid fuel cell (PAFC)

Solid Oxide fuel cell (SOFC) - Alkaline fuel cell (AFC) - High-temperature fuel cells - Electric storage fuel cell - Comparison of fuel cell types- Batteries – Micro Algae – Biodiesel from Algae

Text Book:

1. G L Johnson, *Wind Energy Systems*, Prentice Hall Inc., New Jersey, 1985.
2. David A. Spera, (Editor) *Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering,* American Society of Mechanical Engineers; (1994)
3. Tong Jiandong(et al.) , *Mini Hydropower ,* John Wiley, 1997

References:

1. Erich Hau,*Wind Turbines: Fundamentals, Technologies, Application and Economics,* Springer Verlag; (2000)
2. Paul Gipe , Karen Perez, *Wind Energy Basics: A Guide to Small and Micro Wind Systems,* Chelsea Green Publishing Company; (1999)
3. J. F. Manwell, J. G. McGowan, A. L. Rogers, *Wind Energy Explained ,* John Wiley & Sons; 1st edition (2002)
4. Tony Burton, David Sharpe, Nick Jenkins, Ervin Bossanyi, *Wind Energy Handbook ,* John Wiley & Sons; 1st edition (2001)
5. Mukund R. Patel, *Wind and Solar Power Systems ,* CRC Press; (1999)
6. John F. Walker and Nicholas Jenkins, *Wind Energy Technology,* John Wiley, 1997

Course Outcomes

At the end of the course learner will be able to

- ✓ Develop basic knowledge about Wind energy conversion Technology and its terminologies.
- ✓ Design and assess the small wind turbine and its performance.
- ✓ Enumerate the Small mini Hydro plants for Energy generation.
- ✓ Selecting the Hydro power plant capacity for the given circumstances.
- ✓ Develop the basic technological idea about various New & Renewable energy conversion Technology.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	-	2	2	-	-	2	3	3	3	3	-	2
2	3	3	-	2	2	-	-	2	3	3	3	3	-	2
3	2	3	-	3	2	3	3	3	3	3	3	3	2	2
4	2	2	1	3	1	3	3	3	3	3	3	2	2	3
5	-	3	-	3	-	2	3	3	3	3	3	2	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD1101	Energy Auditing and Conservation	3	4	0	0	40	60	100

Course Objectives:

CO1 : Familiarize with energy management
CO2 : Carryout energy analysis of thermal system
CO3 : Study the energy conversion in electrical utilities
CO4 : Increase the rational use of energy in process / product industries.
CO5 : Analyze the impact on energy efficiency on environment

Cognitive Level:

K1 : Identify various key factors for performance evaluation of thermal & electrical Systems
K2 : Describe the direct and indirect methodologies used for the performance Evaluation of thermal and electrical utilities
K3 : Calculate the efficiency of various utilities and suggest methods for energy Conservation.
K4 : Conduct energy audit, analyze the data using software techniques and suggest Economic measures for energy conservation.
K5 : Apply energy management systems and use management matrix as a tool to Prepare an action plan for improving theperformance of any organization / Industry.

Unit I:

Energy Conservation Act-2001 and its Features. Energy management and audit : Definition, energy audit – need, types of energy audit, energy management (audit) approach – understanding energy costs, benchmarking, energy performance Matching energy use to requirement, Maximizing system efficiencies,Optimizing the input energy requirements, Fuel and energy substitution, Energy auditinstruments

Global environmental concerns: United Nations framework convention on climate change (UNFCC), Kyoto protocol, conference of parties (COP), clean development mechanism (CDM), prototype carbon fund (PCF), sustainable development. Practices for sequester carbon, carbon sequestration types, carbon testing, credits, and economics.

Unit II:

Basics of energy & its various forms : Thermal basics – fuels, thermal energy content of fuels, temperature and pressure, heat capacity, sensible & latent heat, evaporation, condensation, steam, moist air, humidity and heat transfer, units and conversion. – Thermodynamic properties of pure substances in solid, liquid and vapor phases, P-V-T behavior of simple compressible substances, phase rule, thermodynamic property tables and charts.

Boilers: Types, combustion in boilers, performance evaluation, analysis of losses, feed water treatment, blow down, energy conservation opportunities.

Unit III:

Heat Transfer Fundamentals – Conduction – Convection – Radiation - Furnaces: Classification, general fuel economy measures in furnaces, excess air, heat distribution, temperature control, draft control, waste heat recovery. Insulation and Refractories: Insulation-types and

application, Economic thickness of insulation, Heat savings and application criteria, Refractory-types, selection and application of refractories, Heat loss.

Unit IV:

HVAC and Refrigeration System:Vapor compression refrigeration cycle, Refrigerants, Coefficient of performance, Capacity, Factors affecting Refrigeration and Air conditioning system performance and savings opportunities. Vapor absorption refrigeration system**:** Working principle, Types and comparison with vapor compression system, saving potential

Unit: V

Electricity basics – DC and AC currents, electricity tariff, load management and maximum demand control, power factor. Electric motors:Types, Losses in induction motors, Motor efficiency, Factors affecting motor performance, Rewinding and motor replacement issues, Energy saving opportunities with energy efficient motors. Energy Efficient Technologies in Electrical Systems**:** Maximum demand controllers, Automatic power factor controllers, Energy efficient motors, and Soft starters with energy saver, Variable speed drives, and Energy efficient transformers. Lighting System: Light source, Choice of lighting, Luminance requirements, and Energy conservation avenues

Text Book:

1. CB Smith, *Energy Management Principles*, Pergamon Press, New York, 1981
2. Bureau of Energy Efficiency: *Study material for Energy Managers and Auditors Examination*: *Paper I to IV*.2006
3. Hamies, *Energy Auditing and Conservation; Methods, Measurements, Management & Case study*, Hemisphere, Washington, 1980

References:

1. D Patrick and S W Fardo, *Energy Management and Conservation*, Prentice Hall Inc., 1996
2. Thuman A and Mehta D Paul, *Handbook of Energy Engineering*, The Fairmount Press., 1998
3. Kennedy, Turner and Capehart, *Guide to Energy Management*, The Fairmount Press., 1996
4. Wayne C Turner, *Energy Management Handbook*, The Fairmount Press., 2000
5. Kao Chen, *Energy Management in Illumination System*, CRC Press, 2000
6. Gellingn, Chamberli, *Demand Side Management: Concepts and methods*, Penwell, 1998
7. Charles M Cotlschalk, *Industrial Energy Conservation*, John Wiley & Sons, 2002

Course Outcomes

At the end of the course learner will be able to

- ✓ Describe and formulate basic –auditing terms.
- ✓ Define and analyze the auditing approaches for a selective industry.
- ✓ Evaluate the performance analysis and optimization of thermal utilities.
- ✓ Formulate energy action planning for various types of industry.
- ✓ Describe and categorize the global environmental concerns for effective energy conservation and compare with international standards.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	2	2	3	3	3	2	-	3	3	3	3	-	3
2	3	2	1	3	3	3	2	-	3	3	3	2	-	3
3	3	2	1	3	3	3	2	-	3	3	3	2	-	3
4	3	2	1	3	3	3	2	-	3	3	3	2	-	3
5	3	3	2	3	3	3	2	2	3	3	3	3	2	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD1102	Optimum Utilization of Heat And Power	3	4	0	0	40	60	100

Course Objectives:

CO1 : Impart importance of optimum utilization of heat and power in process and product industry
CO2 : Study the impact of CHP on environment
CO3 : Optimize the CHP usage
CO4 : Design of CHP
CO5 : Integrate CHP with RE system

Cognitive Level:

K1 : Identify various key factors in CHP System
K2 : Performance evaluation of CHP System
K3 : Calculate the efficiency of various process and integration of CHP
K4 : Data analysis using software techniques and suggest economic measures
K5 : Design a new CHP technique for process industry

Unit I

Basic concepts of CHP- The benefits and problems with CHP –Balance of energy demand– Types of prime movers - Economics– CHP in various sectors. Application & techno economics of Cogeneration- Cogeneration -Performance calculations, Part load characteristics- financial considerations - Operating and Investments

Unit II

Pinch Technology–significance– Selection of pinch temperature difference – Stream splitting – Process retrofit – Installation of heat pumps, heat engines - Grand composite curve.

Unit III

Insulation – Recuperative heat exchanger – Run –around coil systems – Regenerative heat exchangers – Heat pumps – Heat pipes –. Waste Heat Recovery -Cogeneration Technology

Unit IV

Sources of waste heat, Cogeneration - Principles of Thermodynamics - Combined Cycles- Topping -Bottoming - Organic Rankine Cycles- Advantages of Cogeneration Technology

Unit V

Application & techno economics of Cogeneration- Cogeneration - Performance calculations, Part load characteristics- financial considerations - Operating and Investments

Text Book:

1. Eastop, T.D. & Croft D.R, "Energy efficiency for engineers and Technologists", 2ndedition, Longman Harlow, 1990.
2. O"Callaghan, Paul W, "Design and Management for energy conservation", Pergamon, 1993.

REFERENCES:

1. Osborn, peter D, "Handbook of energy data and calculations including directory of products and services", Butterworths, 1980.
2. Charles H.Butler, Cogeneration, McGraw Hill Book Co., 1984.
3. Horlock JH, Cogeneration - Heat and Power, Thermodynamics and Economics, Oxford,1987

Course Outcomes

At the end of the course learner will be able to

- ✓ List and analyze the possibilities of combined Heat and power generation methodology for various sectors.
- ✓ Develop and assess pinch technology with process retrofits.
- ✓ Enumerate and evaluate the critical thickness of insulation.
- ✓ List the economical features & factors involving in cogeneration techniques

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	3	3	3	2	1	1	3	3	3	3	1	3
2	3	3	1	3	3	3	2	1	3	3	3	2	1	3
3	3	3	1	3	3	3	2	1	3	3	3	2	1	3
4	3	3	2	3	3	3	2	1	3	3	3	3	2	3
5	3	3	2	3	3	3	2	1	3	3	3	3	2	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD1103	Thermodynamic Analysis of Energy Systems	3	4	0	0	40	60	100

Course Objectives:

CO1 : Understand and apply the concept of availability,
CO2 : Calculate the behavior of real gases
CO3 : Predict the condition of systems and analyze them by the criteria of equilibrium
CO4 : Apply the concepts of advanced thermodynamics to combustion systems
CO5 : Analyze the thermal performance of RE Devices

Cognitive Level:

K1 : Various Definition of Thermodynamics
K2 : Performance evaluation of Thermal System
K3 : Calculate the efficiency of various thermodynamics process
K4 : Data analysis using software techniques and suggest economic measures
K5 : Design and optimize the performance thermal process in an industry

Unit I

Reversible work - availability – irreversibility. Second law efficiency for a closed system and steady – state control volume. Availability analysis of simple cycles. Thermodynamic potentials. Maxwell relations. Generalized relations for changes in entropy - internal energy and enthalpy- Cp and CV. Clausius Clayperon equation, Joule – Thomson coefficient. Bridgeman tables for thermodynamic relations

Unit II

Different equations of state – fugacity – compressibility. Principle of Corresponding States – Use of generalized charts for enthalpy and entropy departure. Fugacity coefficient, Lee – Kesler generalized three parameter tables. Fundamental property relations for systems of variable composition. Partial molar properties. Ideal and real gas mixtures. Equilibrium in multi-phase systems.

Unit III

First and second law analysis of reacting systems - Adiabatic flame temperature – entropy change of reacting systems. Criterion for reaction equilibrium. Equilibrium constant for gaseous mixtures and evaluation of equilibrium composition.

Unit IV

Combustion of Hydrocarbon Fuels. The heat of reaction, combustion, and formation. Stoichiometric, fuel-rich, and oxygen-rich reactions. Heating value of fuels. Application of energy equation to the combustion process. Explosion limits, flames, and flammability limits. Diffusion and premixed flames.

Unit V

Combustion in IC Engines and Gas turbines. Knocking and Detonation and control. Design principles of combustion chambers for IC Engines and Gas turbines. Arrangements of gas turbine combustion chambers for power and comparative analysis.

Text Book:

1. Bejan, A., Advanced Engineering Thermodynamics, John Wiley and Cons, 1988.
2. Kuo, K.K., Principles of Combustion, John Wiley and Sons, 2005

REFERENCES:

1. Kenneth Wark Jr., Advanced Thermodynamics for Engineers, McGrew – Hill Inc., 1995.
2. Winterbone D E, Advanced Thermodynamics for Engineers, Arnold, 1997.
3. Ganesan, V., Gas Turbines, Tata McGraw Hill, 2011.
4. Ganesan,V., Internal Combustion Engines, Tata McGraw Hill, 2006
5. Natarajan, E., Engineering Thermodynamics – Fundamentals and Applications, Anuragam2014.
6. Cohen, H., Rogers, G F C and Saravanmotto, H I H, Gas Turbine Theory, John Wiley, 2001.

Course Outcomes

At the end of the course students will be able to

- ✓ Calculate the availability of the systems and cycles
- ✓ Analyse the engineering systems to improve and optimize its performance
- ✓ Understand the working and design principles of combustion systems

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	1	3	3	3	1	1	3	3	3	3	2	3
2	3	3	1	2	2	2	2	1	3	3	3	2	2	3
3	3	3	2	3	3	3	2	1	3	3	3	2	2	3
4	3	3	2	3	2	3	2	1	3	3	3	2	2	2
5	3	3	3	3	2	3	2	2	3	3	3	2	2	2

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD1104	Instrumentation for Energy Systems	3	4	0	0	40	60	100

Course Objectives:

CO1 : To impart knowledge about characteristics of measurement system and statistical analysis of measured data.

CO2 : To make students conversant with the electrical measurements and signal Conditioning circuits.

CO3 : To provide insight into the digital measuring techniques of physical quantities and Solar instruments.

CO4 : To make the students get acquainted with the measurement of thermo-physical Properties and air pollutants.

CO5 : To inculcate skills in the design and development of measurement and control Systems.

Cognitive Level:

K1 : Various Definition of measurement

K2 : Error analysis

K3 : Measurement of different properties

K4 : Data recording and analysis

K5 : Design and optimize the control systems for renewable energy sources

UNIT – I

Introduction to measurement system, Errors in Measurement, Static and Dynamic characteristics of transducers, Statistical analysis of experimental data – Uncertainty analysis, Regression analysis, Design of experiments – Full and Half factorial design.

UNIT – II

Voltage, Current, Power, Energy, Time and Frequency measurement, Frequency Counter, Signal conditioning Circuits: Wheatstone bridge – Differential Amplifier – V to I Converter, I to V Converter, Integrator, Differentiator, Instrumentation Amplifier, Attenuators and Filters, DAC, ADC, PID Controller.

UNIT – III

Digital measuring techniques of Displacement, Temperature, Pressure, Force, Torque, Vibration, Acceleration, Velocity, Level, Flow, Thermal and Nuclear Radiation. Solar instruments: Pyrheliometers – Pyranometers– Pyrheliometers – Albedometers – Pyrradiometers – Pyrgeometers – Net Pyrradiometers – Sunphotometers.

UNIT – IV

Measurement of Thermal Conductivity – Solids, Liquids and Gas, Viscosity, Gas Diffusion. Calorimetry – Bomb Calorimeter – Continuous flow Calorimeter. Measurement of Heat Transfer, Humidity, Heat flux, pH, Air pollution Sampling and Measurement – Particulate Sampling techniques – Measurement of Sulphur Dioxide, Combustion products, Opacity and Odour.

UNIT – V

Introduction to Arduino and Raspberry Pi – Interfacing with I/O devices of system: Sensors, Display devices, Stepper and Servo motors. Measurement by Data Acquisition System. Introduction to Internet of Things (IoT) – Application of IoT with Raspberry Pi for Process monitoring and control – Energy management. Application of PID controller in PV and Energy systems. Application of Smart Sensors and Intelligent instrumentation and Control.

Text Book:

1. Barney G.C., "Intelligent instrumentation: microprocessor applications in measurement and control", Prentice Hall, 1988.
2. John P. Bentley "Principles of Measurement System" Pearson Education, 2012.
3. Bell C., "Beginning Sensor Networks with Arduino and Raspberry Pi", Apress, 2013.

REFERENCES:

1. Doebelin E. and ManikD.N., "Doebelin's Measurement Systems", Tata McGraw Hill, 2011.
2. George, B., Roy, J.K., Kumar, V.J., Mukhopadhyay, S.C., "Advanced Interfacing Techniques for Sensors", Springer, 2017.
3. Holman J.P., "Experimental methods for Engineers", Tata McGraw Hill, 2007.

Course Outcomes:

Upon completion of this course, the students will be able to:

- ✓ Analyze and evaluate the uncertainties in measurement data.
- ✓ Identify appropriate sensors for measuring electrical quantities and signal conditioning circuits
- ✓ Explain the digital measurement techniques of physical quantities.
- ✓ Implement the measurement of thermo-physical properties and air pollutants.
- ✓ Design and develop the appropriate measurement and control system for an application.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	1	3	3	3	1	1	3	3	3	3	2	3
2	3	3	1	2	2	2	2	1	3	3	3	2	2	3
3	3	3	2	3	3	3	2	1	3	3	3	2	2	3
4	3	3	2	3	2	3	2	1	3	3	3	2	2	2
5	3	3	3	3	2	3	2	2	3	3	3	2	2	2

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD1105	Advanced Numerical Analysis	3	4	0	0	40	60	100

Course Objectives:

CO1 : Solving of Simultaneous Equation
CO2 : Curve Fitting
CO3 : Numerical Solution of Differential Equation
CO4 : Develop of theory and practice in the use of advanced numerical methods for Efficient solution of differential equation in renewable energy engineering.
CO5 : Formulate the renewable energy device performance in the form of numerical Equations

Cognitive Level:

K1 : Understanding various terminologies in Numerical Analysis
K2 : Performance of simple iterations
K3 : Calculate the numerical solution using differentiation and integration
K4 : Renewable Data analysis using Numerical Methods
K5 : Design and optimize the performance of Renewable Energy system using Numerical Technique

Unit I

Solving a system of simultaneous equations; elimination method – the Gaussian elimination and Gauss - Jordan method – Iterative methods – Gauss Jacobi iteration – Gauss Seidel iteration - Relaxation method.

Unit II

Interpolation and curve fitting: Lagrangian polynomials - Divided difference – Interpolation with cubic spline - Least square approximation of functions.

Numerical Solutions of nonlinear system of equations – Fixed points for functions of several variables – Newton's method – Quasi Newton Methods – Steepost Descent Techniques – Homotopy and continuation methods

Unit III

Numerical differentiation and integration: Numerical differentiation – derivatives using Newton's forward and backward formula –Derivatives using Striling's formula – Trapezoidal rule – Simpson's $1/3^{rd}$ rule – 3/8 rule – Weddles's rules – Errors in quadrature formula. – Moulton method.

Numerical Matrix Eigen value problems – Eigen value problems arising in practical applications – Localization of Eigen values – compting selected Eigen values and Eigen vectors – the power method – the inverse iteration - the Rayliegh Quotient interations –Similarity tranformations and Eigen value computations

Unit IV

Numerical solution of ordinary differential equations: the Taylor series method – Picard's method Euler and modified Euler methods – Runge – Kutta methods – Milne's method – The Adams – Moulton method.

Unit V

Numerical solution of Partial differential equations – Introduction - Difference quotients – Geometrical representation of partial differential quotients – Classification of partial differential equations - Elliptic equations – Solutions to Laplace's equation by Liebmann's iteration process – Poission's equations and its solutions – Parabolic equations – Crank – Nicholson method - Hyperbolic equations.

Text Book:

1. Curtis. F. Gerald, Patrick & O. Wheatley, Applied Numerical Analysis, 5th Edition, Pearson Education, New Delhi, 2005.
   Unit 1: Chapter 2: Sections 2.3, 2.4, 2.10, 2.11
   Unit 2: Chapter 3: Sections 3.1, 3.2, 3.3, 3.4, 3.7.
2. V.N Vedamurthy & N.Ch.S.N.Iyengar, Numerical Methods, Vikas Publishing house, pvt. Ltd, 2000.
   Unit 3: Chapter 9: Sections 9.1 to 9.4, 9.6 to 9.12.
   Unit 4: Chapter 11: Sections 11.4 to 11.20.
   Unit 5: Chapter 12: Sections 12.1 to 12.9.

REFERENCES

1. Richard L. Burden & J.Douglas Faires, Numerical Analysis, 7th Ed., Thomson Brooks , 2001
2. Biswa Nath Datta, Numerical Linear Algebra, 2nd Ed., PHI Learning P Ltd., 2013
3. M.K.Jain, S.R.K Iyengar & R.K.Jain, Numerical Methods for Scientific and Engineering Computation, 3r Edition, Wiley Eastern Edition, New Delhi, 2003.
4. R.L.Burden & J.Douglas Faires, Numerical Analysis, Thompson Books, USA, 2005.

Course Outcomes

At the end of the course learner will be able to

- ✓ Apply mathematical concepts and principles in renewable energy technology.
- ✓ Perform abstract mathematical reasoning.
- ✓ Understand the application of Fourier transform in engineering application.
- ✓ Apply conformal mapping for heat flow & fluid flow problems.
- ✓ Develop Finite difference methods for elliptical and parabolic equations.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	2	2	2	1	1	1	1	3	3	2	2	2
2	3	3	2	2	2	1	1	1	1	3	3	2	2	2
3	3	3	2	2	2	1	1	1	1	3	3	2	2	2
4	3	3	3	3	3	2	2	1	3	3	3	3	1	3
5	3	3	3	3	3	2	2	1	3	3	3	3	1	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD1106	GHG Accounting and Sustainability Reporting	3	4	0	0	40	60	100

Course Objectives:

CO1 : Familiarize with carbon accounting technique
CO2 : Carryout carbon quantification analysis of renewable energy projects
CO3 : Study the carbon accounting in renewable energy utilities
CO4 : Increase the rational use of energy through proper carbon emission reduction
CO5 : Analyze the carbon accounting process for sustainable development

Cognitive Level:

K1 : Identify various key parameters for carbon accounting of renewable energy projects
K2 : Describe the systematic methodology for carbon quantification and assessment
K3 : Critically evaluate carbon accounting statements, whether in the financial accounts, footprinting reports, carbon disclosure reports etc.
K4 : Critically evaluate alternative approaches to carbon accounting.
K5 : Conceptualise and apply the vital strategic reflections associated with carbon accounting.

Unit-1: Introduction: Carbon and Climate Change

Overview of the causes and effects of climate change -Introduction to carbon finance and its role in mitigating climate change- Climate change Mitigation: NDCs and Net Zero Goal Market mechanisms under the Paris Climate Agreement Carbon capture, utilisation and storage (CCUS). Fundamentals of Carbon Pricing, Market Failures, Externalities, Coase Theorem, Carbon Taxes, Carbon Markets, Institutional Topics in Cap-and-Trade International Carbon Markets and Future of Carbon Pricing

Unit-2 : Carbon Accounting and Measurement

Introduction to GHG emissions inventories- overview of GHG emissions inventories, including the types of GHG emissions and sources-the importance of GHG emissions inventories, and the methods used to calculate emissions - Measurement methodologies and protocols (e.g., IPCC, ISO) with emission reporting as per IPCC and ISO standards and guidelines.

Unit-3: Carbon Pricing and Offsetting

Understanding the concept of carbon pricing and its role in mitigating climate change - the concept of carbon pricing, its purpose, and its impact on climate change mitigation efforts - Types of carbon pricing mechanisms (e.g., carbon tax, cap-and-trade)- types of carbon pricing mechanisms- prospects and restraints of carbon pricing methodologies- Design and implementation of carbon pricing policies - Principles of carbon offsetting and its role in mitigating GHG emissions - Types of carbon offset projects (e.g., renewable energy, energy efficiency, forestry).

Unit-4: Carbon Assessment Techniques

Gases, Sectors, and methodologies Policies, regulations and protocols Estimation of carbon footprint-IPCC guidelines for National GHG inventories.- Carbon Border Adjustment Mechanism: CBAM and its Operation Rules. Its Impact on Cross-border Trade and Developing

and Developed Countries Relations, CBAM and Carbon Leakage and its Impact on Carbon Offset Market. Basic concept of EIA : Initial environmental Examination, Elements of EIA, - factors affecting E-I-A Impact evaluation and analysis, preparation of Environmental Base map, Classification of environmental parameters, E I A Methodologies for sustainably.

Unit-5: Emission Trading in India

BEE initiatives on Energy Performance analysis, Energy auditing, PAT Analysis, Escerts and RECs Specifications, Trading of Escerts and RECs on Energy Exchanges. Future Directions of Carbon Trading in India

Text Book:

1. Arnaud Brohé (2016) "The Handbook of Carbon Accounting" by A Greenleaf publishing book, Routledge Taylor and Fransis Group, New York, USA. ISBN-: 978-1783533176
2. Scott Deatherage (2011) "Carbon Trading Law and Practice" by Oxford University Press, USA ISBN: 9780199732240.
3. Gilbert M. Masters and Wendell P. Ela. Introduction to Environmental Engineering and Science. 3rd edition. PHI learnings, New Delhi (2007)

References :

1. Sonia Labatt, Rodney R. White (2007), " Carbon Finance: The Financial Implications of Climate Change" Wiley, ISBN: 9780471794677
2. UNDP, Carbon Handbook, United Nations Development Programme (2014)
3. Gupta M. Restricting Greenhouse Gas Emissions: Economic Implications for India, New Delhi. (2006)

Course Outcome:

1. Understand and critically discuss the range of measurement, calculation, reporting, and auditing requirements and challenges imposed by climate change and the policy responses to climate change
2. Understand and critically evaluate the main drivers for carbon accounting and have an appreciation for how they may change over time
3. Explain and discuss the relationship between conventional accounting and carbon accounting
4. Critically discuss the ethical questions raised by carbon accounting and the risks associated with different accounting practices
5. Understand and critically evaluate the difference between attributional greenhouse gas inventories and consequential assessments

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	2	2	2	1	1	1	1	3	3	2	2	2
2	3	3	2	2	2	1	1	1	1	3	3	2	2	2
3	3	3	2	2	2	1	1	1	1	3	3	2	2	2
4	3	3	3	3	3	2	2	1	3	3	3	3	1	3
5	3	3	3	3	3	2	2	1	3	3	3	3	1	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD1107	Computational Fluid Dynamics	3	4	0	0	40	60	100

Course Objectives:

CO1 : Provide Computational Fluid Dynamics analysis of Renewable Energy application
CO2 : Formulation of CFD problems with different boundary conditions
CO3 : Able to mesh Different Geometry
CO4 : Understand the solver of fluid mechanics and heat transfer related problems.
CO5 : Simulation of Renewable energy device performance

Cognitive Level:

K1 : Understanding various terminologies in CFD
K2 : Governing Equation analysis
K3 : Calculate the meshing quality
K4 : Renewable Data analysis using CFD
K5 : Design and optimize the performance of Renewable Energy system using CFD

Unit I

Illustration of the CFD approach, CFD as an engineering analysis tool, Review of governing equations, modeling in engineering, Partial differential equations- Parabolic, Hyperbolic and Elliptic equation, CFD application in Engineering, CFD software packages and tools.

Unit II

Principles of Solution of the Governing Equations: Finite difference and Finite volume Methods, Convergence, Consistency, Error and Stability, Accuracy, Boundary conditions, CFD model formulation.

Unit III

Mesh generation: Overview of mesh generation, Structured and Unstructured mesh, Guideline on mesh quality and design, Mesh refinement and adaptation. Solution Algorithms: Discretization schemes for pressure, momentum and energy equations - Explicit and implicit Schemes, First order upwind scheme, second order upwind scheme, QUICK scheme, SIMPLE, SIMPLER and MAC algorithm, pressure-velocity coupling algorithms, velocity-stream function approach, solution of Navier-Stokes equations.

Unit IV

CFD Solution Procedure: Problem setup – creation of geometry, mesh generation, selection of physics and fluid properties, initialization, solution control and convergence monitoring, results reports and visualization.

Unit V

Case Studies: Benchmarking, validation, Simulation of CFD problems by use of general CFD software, Simulation of coupled heat, mass and momentum transfer problem.

Text Book

1. P.S. Ghosdastidar, Computer Simulation of Flow and Heat Transfer, Tata McGraw-Hill (1998).
2. Muralidhar, K., andSundararajan, T. Computational Fluid Flow and Heat Transfer, Narosa Publishing. House (1995)

References:

1. Niyogi, P. Chakrabarty, S.K. and Laha, M.K., Introduction to computational fluid dynamics, Pearson education (2006).
2. LI J., G. H. Yeoh, C Liu. A Computational Fluid Dynamics, ELSEVER (2008)
3. Suhas V. Patankar. Numerical Heat Transfer and Fluid Flow, Taylor and Francis (1978).
4. S K Gupta. Numerical Methods for Engineers, New Age Publishers, 2nd Edition (1995).
5. Anderson J.D. Computational Fluid Dynamics, Mc-Graw Hills (1995).
6. Ranade, V.V., Computational flow modeling for chemical reactor engineering, Academic Press (2002).
7. J H Ferziger and M Peric, Computational Methods for Fluid Dynamics, Springer (2002).

Course Outcomes:

Upon completion of this course, the students will be able to:

- ✓ Solve PDE.
- ✓ Use Finite Difference and Finite Volume methods in CFD modelling
- ✓ Generate and optimize the numerical mesh
- ✓ Simulate simple CFD models and analyse its results.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	2	2	3	3	1	-	3	3	3	3	-	3
2	3	3	2	-	3	2	2	-	3	3	3	3	-	3
3	3	3	2	1	2	3	2	-	3	3	3	3	-	3
4	3	3	3	2	2	2	2	-	3	3	3	3	-	3
5	3	3	2	2	2	2	1	-	3	3	3	3	-	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD1108	Optimization Techniques for Sustainability	3	4	0	0	40	60	100

Course Objectives:

CO1 : Able to use relevant optimization techniques for effective energy harnessing.
CO2 : Model different types of renewable energy mix for optimum usage
CO3 : Analyze Demand Forecasting and Modeling of Energy System
CO4 : Understand role of renewable in demand increase
CO5 : Study the optimization model of RE Projects

Cognitive Level:

K1 : Understanding various fundamentals of Energy optimization techniques
K2 : Analysis of Energy Optimization tools
K3 : Interpret Energy Optimization with RE mix for sustainable development
K4 : Analysis of optimization techniques for sound hybrid energy planning
K5 : Design and Cost Economics analysis of RE project management system

Unit-1

Introduction to optimization theory, design and system design. Morphology of design with a flow chart. A very brief discussion on market analysis, profit, time value of money, and an example of discounted cash flow technique. Concept of workable design, practical example on workable system and optimal design. importance in solving system engineering problems Classification of optimization problems, Classical Optimization Techniques, Single and Multiple Optimization with and without inequality constraints.

Unit-2

System Simulation, Classification. Successive substitution method - examples. Newton Raphson method – one unknown - examples. Newton Raphson method - multiple unknowns - examples. Gauss Seidel method - examples. Rudiments of finite difference method for partial differential equations.

Unit-3 Regression and Curve Fitting

Need for regression in simulation and optimization. Concept of best fit and exact fit. Exact fit - Lagrange interpolation, Newton's divided difference - examples. Least square regression - theory, examples from linear regression with one and more unknowns -examples. Power law forms - examples. Gauss Newton method for nonlinear least squares.

Unit-4: Optimization Techniques

Introduction, Formulation of optimization problems. Calculus techniques – Lagrange multiplier method – proof, examples. Search methods – Concept of interval of uncertainty, reduction ratio, reduction ratios of simple search techniques like exhaustive search, dichotomous search, Fibonacci search and Golden section search – numerical examples. Method of steepest ascent/steepest descent, conjugate gradient method – Geometric programming.

Unit-5: Dynamic and Linear Programming

Dynamic programming – examples. Linear programming – two variable problem –graphical solution. New generation optimization techniques – Genetic algorithm and simulated annealing - examples. Introduction to Bayesian framework for optimization examples.

Text Book:

1. NPTEL MOOC reference: Design and Optimization of Energy systems by Prof. C. Balaji, Department of Mechanical Engineering, IIT madras.
2. Essentials of Thermal System Design and Optimization, Prof. C. Balaji, Aue Books, New Delhi in India and CRC Press in the rest of the world.
3. Computational methods in Optimization, Polak, Academic Press, 1971.
4. Optimization Theory with applications, Pierre D.A.,WileyPublications, 1969.

References:

1. S.S.Rao,"Optimization–TheoryandApplications",Wiley-Eastern Limited, 1984.
2. G.Luenberger," Introduction of Linear and Non-Linear Programming",Wesley Publishing Company, 2011
3. Design and optimization of thermal systems, Y.Jaluria, McGraw Hill, 1998.
4. Design of thermal systems, W.F.Stoecker, Mc Graw Hill,1989.
5. Optimization for engineering design - algorithms & examples, K.Deb, Prentice Hall, 1995.

Course Outcomes

- ✓ The students would have understood the importance of energy in economic development and need for energy conservation.
- ✓ They also be able to take up research in energy economics.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	2	2	2	3	3	3	3	2	3	3	3	3	2	3
2	2	2	2	3	3	3	3	3	3	3	3	3	2	3
3	2	2	2	3	3	3	3	3	3	3	3	3	2	3
4	2	2	2	3	3	3	3	3	3	3	3	3	2	3
5	2	2	2	3	3	3	3	3	3	3	3	3	2	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPC1103	Solar Energy Laboratory	3	0	0	4	60	40	100

Course Objectives:

CO1 : Carryout the performance evaluation of solar thermal system
CO2 : Optimize the performance of solar thermal devices
CO3 : Carryout the performance evaluation of Solar PV system
CO2 : Optimize the performance of solar photovoltaic conversion devices
CO3 : Simulate the system using tools

Cognitive Level:

K3 : Calculate the efficiency of solar thermal and electrical system
K4 : Performance analysis of solar devices
K5 : Design and optimize the performance of Solar Thermal & Electrical System

1. Study on greenhouse effect on solar flat plate collector
2. Estimation of instantaneous efficiency of a solar liquid flat plate collector
3. Study on solar flat plate collectors in series and parallel combination
4. Estimation of efficiency of solar air heaters
5. Estimation of efficiency of solar still
6. Performance evaluation of concentrating solar collector
7. Performance evaluation of solar cooker
8. Estimation of efficiency of solar photovoltaic panels
9. Effect of Shadow & tilt angle on solar photo voltaic panel
10. Performance analysis of solar photo voltaic panel in series and parallel combination
11. Performance analysis of charging characteristics of a lead acid battery using solar photo voltaic panel.
12. Performance analysis of String inverter
13. Performance analysis of Micro inverter
14. Performance analysis of Power optimizer

Course Outcomes

At the end of the course learner will be able to
Evaluate the performance of

- ✓ Solar thermal system
- ✓ Solar PV system

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	2	2	3	2	3	3	3	3	3	3	3	3	-	3
2	2	3	3	2	3	3	3	2	3	3	3	3	-	3
3	2	3	3	2	3	3	3	2	3	3	3	3	-	3
4	3	3	2	2	2	3	2	2	3	3	3	3	-	3
5	3	3	2	2	2	3	2	2	3	3	3	3	-	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPC1104	Wind Energy Laboratory	3	0	0	4	60	40	100

Course Objectives:

CO1 : Analyze wind potential mapping
CO2 **:** Carryout the performance evaluation of wind electrical System
CO3 : Carry out the performance analysis of wind mechanical system
CO4 : Study the grid integration of Wind system
CO5 : Simulate and carryout the performance testing of Renewable Energy Devices Using software tools

Cognitive Level:

K3 : Calculate the efficiency of wind energy conversion systems
K4 : Performance analysis of wind electric generators
K5 : Design and optimize the performance of wind water pumping system

1. Estimation of cut in velocity of wind turbine generator
2. Evaluation of Tip Speed Ratio (TSR) with different wind velocities
3. Estimation of Coefficient of Performance of Wind Electric Generator
4. Evaluation of Power curve for wind turbine generator
5. Estimation of Charge controller of Wind Turbines
6. Performance evaluation of Wind turbine generator with various AC load condition
7. Performance evaluation of Wind turbine generator with various DC load condition
8. Performance Evaluation of Wind Water Pumping System
9. Study on Grid Integration of Wind Electric Generator
10. Studies on Micro Wind Turbine system
11. Performance analysis of Hybrid inverter
12. Simulation using Open Source Software (Spoken Tutorials, IIT, Bombay)

Course Outcomes

At the end of the course learner will be able to evaluate the performance of

- ✓ Wind Electric
- ✓ Wind Pumping

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	3	2	3	3	3	3	3	3	3	3	2	3
2	**2**	3	3	2	3	3	3	2	3	3	3	3	-	3
3	2	3	3	2	3	3	3	2	3	3	3	3	-	3
4	2	3	3	2	3	3	3	2	3	3	3	3	-	3
5	2	2	2	2	3	3	3	2	3	3	3	3	-	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPC1105	Research Methodology and IPR	4	4	0	0	40	60	100

Cognitive Level	**K-1** Understanding various terminologies in Research Methods
	K-2 Analysis of Statistical Data
	K-3 Calculate the Probability
Course Objectives	**The Course aims to** • identify and formulate a problem for research. • prepare suitable research design, choose appropriate tools and techniques of data collection • process the data collected and do analysis using appropriate statistical methods • write research report independently and professionally

UNIT	Content	No. of Hours
I	Scientific Research – methods of acquiring knowledge - Inductive and Deductive Reasoning, scientific method and its applications. New Developments in IPR: Administration of Patent System - Traditional Knowledge Case Studies. Plagiarism. Research Process: Selection of Research problem, Review of literature-Systematic review-Meta analysis. Formulation of Hypothesis, Nature and Types of Variable.	**12**
II	Research Design: Purpose, preparation and Types of research design – Exploratory, Descriptive, and Experimental. Field survey and evaluation research. Qualitative and Quantitative Studies – Mixed Methods. Multi-disciplinary, Interdisciplinary and Transdisciplinary Research.	**13**
III	Tools and techniques of data collection – Observation, interview, Inquiry Forms, Projective techniques, Focus group discussion, and PRA. Psychological tests-Measurement and scaling techniques-Validity and reliability. Structure and qualities of a Research Report; Dissemination of research findings, Evaluation of Research Report. Publication process.	**13**

IV	Meaning and Definition of statistics: collection, classification and tabulation of statistical data- graphical and diagrammatic representation of statistical data. Measurement of central tendency; mean, Median, Measures of Dispersion: range, Quartile Deviation, Mean Deviation, Standard Deviation. Measures of Skewness and Kurtosis.	**13**
V	Measures of Relationship: Correlation and Regression analysis. Sampling Techniques: Probability and non- Probability sampling, sampling errors. Testing of hypothesis: basic concepts and steps; statistical Tests- Z test, t-test, Chi-square test, ANOVA.	**13**
References	• Gupta.S.C, *Fundamentals of Statistics*, Mumbai: Himalaya Publishing House, 2018. • Kothari.C.R, *Research Methodology*, New Delhi: Wishva Prakashan, 2019. • Panneer Selvam, Research Methodology, New Delhi: PHI Learning Private Ltd, 2014. • Tony Greenfield and Sue Greener, Research Methods for Post Graduates, John Wiley and Sons Ltd, 2016. • W.G.Cochran, Sampling Techniques, Wiley Eastern Ltd, New Delhi, 1985.	
Text Books	• Cauvery.R. and Girija. M, Research Methodology, New Delhi: S.Chand and Company Ltd, 2010. • Gupta, S.P, Statistical Methods, New Delhi; Sultan Chand and Sons, 2012. • Nicholas Walliman, Research Methods: The basics. London; New York: Routledge, 2011. • Venkatachalapathy, S.G., Premraj, H., Statistical Methods, Chennai: Margham publications, 2015. • Vijayalakshmi.G. and Sivapragasam.C, *Research Methods: Tips and Techniques*, Chennai: MJP Publishers, 2009.	
Websites	• https://www.ggu.edu/courses/syllabus.do?id=29059 • https://www.ncrm.ac.uk/ • https://www.scribbr.com/category/methodology/ • https://online-learning.harvard.edu/subject/statistics • http://www.ddegjust.ac.in/studymaterial/mcom/mc-106.pdf • https://www.statisticssolutions.com/spss-statistics-help	
Course Outcomes	On completion of the course, students should be able to do	

	CO1: Develop expertise and skills to undertake independent research inthe renewable energy area CO2: Development research questionnaire CO3: Understand IPR related issues CO4: Apply of statistical tools for the renewable energy system performance CO5: Write research article and prepare project report

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	2	1	3	3	3	3	3	2	3	3	2	3	3
2	3	3	2	3	3	3	3	3	2	3	3	2	3	3
3	1	3	1	3	3	3	3	2	3	3	3	3	2	3
4	2	3	1	3	3	2	3	2	3	3	3	3	2	3
5	2	3	1	3	3	3	3	2	3	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24GTPP001	Gandhi in Everyday Life	**2**	2	0	0	50	0	50

Course Objectives:

- To understand and appreciate the principles and practices of Gandhi and their relevance in the contemporary times.
- To develop noble character and attitude to enable the students to cope up with the challenges of daily life.

Unit - I Understanding Gandhi:Child hood days, Student days, influence of Books and Individuals, Religion, Family, and Social factors. Gandhi as rebel, acquaintance with vegetarianism, as lawyer, encountering and transforming humiliation: in India, in South Africa - train incident, Coach incident, on path way, at court, attack by protesters. Gandhi as political leader and reformer.

Unit - II Management: Gandhi's experiments in managing family- Eleven vows, non-possession and sacrifice begin at home – Managing Ashram - community living, service and financial ethics – Managing Social movements- Transvaal March and Salt Satyagraha and nonattachment to position (Nishkama Seva).

Unit - III Conflict Reduction: Pursuance of truth and nonviolence ends and means, openness, transparence, love and kindness in handling relationship, nonviolent communication, practicing nonviolence in social and political issues (Satyagraha), conflict resolution practices, art of forgiveness and reconciliation and shanti sena.

Unit - IV Humanism: Trust in goodness of human nature, respect for individual and pluralistic nature of society, dignity of differences, equal regard for all religions (Sarvadharma Samabhava), castes, races, colours, languages etc., simple and ethical life, swadeshi and unity of humankind.

Unit - V Constructive programmes and contemporary issues: Concept of Sarvodaya, poverty, terrorism, environmental degradation, problems in sharing common resources, health systems and education, science and technology and centralization of power and governance.

References:

- M.K. Gandhi, (2012) *An Autobiography or The Story of My Experiments with Truth*, Navajivan Publishing House, Ahmedabad.
- (2003) *Satyagraha in South Africa*, Navajivan Publishing House, Ahmadabad.
- (1945) *Constructive Programme: Its Meaning and Place*, Navajivan Publishing House, Ahmadabad.
- (2003) *Key to Health*, Navajivan Publishing House, Ahmedabad
- (1949) *Diet and Diet Reform*, Navajivan Publishing House, Ahmadabad.
- *Basic Education*, Navajivan Publishing House, Ahmadabad.
- (2004) *Village Industries*, Navajivan Publishing House, Ahmadabad.
- (1997) *Hind Swaraj*, Navajivan Publishing House, Ahmadabad.
- (2004) *Trusteeship*, Navajivan Publishing House, Ahmadabad.
- (2001) *India of my Dreams*, Navajivan Publishing House, Ahmadabad.K.S.Bharathi (1995) Thought of Gandhi and Vinoba, *Shanti Sena*, Sarva Seva Sangh Prakashan,

Varanasi.V.P.Varma, (1999) *Political Philosophy of Mahatma Gandhi and Sarvodaya*, Lakshmi Narain Agarwal, Agra.
- Louis Fisher (2010) *Gandhi: His Life and Message*.
- B.R. Nanda. (2011)*Mahatma Gandhi: A Biography*, Allied Publishers Private Ltd., New Delhi.
- N.K. Bose. (2008) *Studies in Gandhism*, Navajivan Publishing House, Ahmadabad.
- Gopinath Dhawan, (2006) *The Political Philosophy of Mahatma Gandhi*, Navajivan Publishing House, Ahmadabad.
- N.Radhakrishnan, (2006) *Gandhi's Constructive Programmes: An Antidote to Globalized Economic Planning?*, Gandhigram Rural Institute, 2006.

Films.

- Richard Attenborough, Gandhi.
- Syam Benegal, the Making of Mahatma.
- Anupam P. Kher, Mine Gandhi Ko Nahin Mara.
- Peter Ackerman and Jack Duvall, A Force More Powerful

Course Outcomes:

To enable students to:

- To study in-depth the life and message of Gandhi.
- To understand the Gandhian way of Management.
- To practice the Gandhian model of conflict reduction.
- To lead a humane life on Gandhian lines.
- To become a Gandhian constructive worker.

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPC1201	Renewable Integrated Power Systems	4	4	0	0	40	60	100

Course Objectives:

CO1 : Get familiarized with the grid integration of renewable power systems
CO2 : Study the various grid integration techniques for rural development
CO3 : To familiarize various IEEE/IEC/BIS standards
CO4 : Design of reliable rural microgrid through grid integration of RES
CO5 : Design of Micro/ Nano grid for rural electrification

Cognitive Level:

K1 : Understanding various Standards IEEE/ IEC/BIS
K2 : Analysis of Power profile of Conventional / Renewable energy systems
K3 : Calculate the Capacity of Solar / Wind & Hybrid Systems grid integration
K4 : Power Quality analysis using various tools
K5 : Design of smart micro/ nano grid for sustainable rural electrification

Unit – I: Introduction

Structure of Power System, Basic aspects of AC power transmission, stability issues in power system, Various techniques of utilizing power from renewable energy sources, the concept of nano/micro/mini-grid. Need of integrating large renewable energy sources, issues related to the integration of large renewable energy sources, rooftop plants. Concept of VPP.

Unit -2 : Grid Synchronization and Stabilization

Synchronous generator: synchronization/integration to the existing grid, load sharing during parallel operation, stability (swing equation and solution), Induction Generator: working principle, classification, stability due to variable speed and countermeasures. Power Electronics: need of power electronic equipments in grid integration, converter, inverter, chopper, AC regulator and cyclo converters for AC/DC conversion. Grid stabilization Scheduling and dispatch, Forecasting, reactive power and voltage control, frequency control, operating reserve, storage systems electric vehicles, Ancillary services in the Indian Electricity Market (regulatory aspect), CERC and CEA orders (technical and safety standards).

Unit-3: Grid Integration of Renewable Energy Sources

Introduction, principles of power injection: converting technologies, power flow; instantaneous active and reactive power control approach; integrating multiple renewable energy sources; DC link integration; AC link integration; HFAC link integration; islanding and interconnection

Unit-4: Electrical Safety and Protection Systems for Renewable Energy Systems

Earthing, Definitions, Classifications, Line and Pole Earthing, Designing, Measurement on Earthing, Guidelines, and Standards, Maintenance of Earthing, Power System Grounding: Ungrounded System, Purpose of Grounding in renewable energy systems, Various types of neutral grounding techniques. Overview of Protection and Switchgear- Equipment and Protective Relays-Functional Design and operational requirements.

Unit: V: Power Quality Management

Power Quality: basic terminologies, the impact of power quality on power factor, true RMS value of current, voltage and power factor(PF), elementary problems, the impact of power quality on the power system, design of transformers & cables in a harmonic environment with illustrations, point of common coupling(PCC), linear and non-linear load, sequence components of harmonics, the impact of harmonics on neutral sizing, power quality audit,

power quality analyzers, power quality issues of solar and wind power integration with grid , power quality standards. Power Quality Mitigation, Reference standards, IEEE, IEC. Smart Grid: Benefits & Technologies of Smart Grid.

Text Book

1. Integration of Alternative sources of Energy, Felix A. Farret and M. Godoy Simoes, IEEE Press – Wiley-Interscience publication, 2006.
2. V.K.Metha: Principles of Power Systems, Chand Publications, New Delhi, 2020.
3. Chetan Singh Solanki: Solar Photovoltaics fundamentals, Technologies and Applications, PHI Learning Private Limited- Eastern Economy Edition
4. Nick Jenkin,Ron Allan,Peter Crossley,DanielKrischen and Goran Strbac: Embedded Generation, IET power and Energy series-31

References

1. Remus Teodorescu,Marco Liserre and Pedro Rodriguez: Grid Converters for Photovoltaic and Wind Power Systems, Wiley and sons Ltd
2. Janaka Ekanayake,Kithsiri Liyanage,Jianzhong Wu,Akihiko Yokoyama,Nick Jenkin: Smart Grid Technology and Applications, A John Wiley & Sons Ltd
3. C.Sankaran: Power Quality, CRC Press
4. Roger C.Dugan, Mark F. McGranaghan,Surya Santoso& H.Wayne Beaty: Electrical Power Systems Quality, Tata McGraw-Hill
5. Dr.P.S.Bimbhra: Electrical Machinery, Khanna Publishers
6. A.ChaKrabarti, M.L.Soni, P.V.Gupta, U.S.Bhatnagar: Power System Engineering, Dhanpat Rai & Co.
7. Grid integration of solar photovoltaic systems, Majid Jamil, M. Rizwan, D.P.Kothari, CRC Press (Taylor & Francis group), 2017
8. Renewable Energy Grid Integration, Marco H. Balderas, Nova Science Publishers, New York, 2009.
9. Power Generation, Operation, and Control, Allen J. Wood, Bruce F. Wollenberg, Gerald B. Sheblé, John Wiley & Sons, New York, 2013 (3rd edition)
10. Advanced power system analysis and dynamics, L.P.Singh, New age international publishers, 2017

Course Outcomes

At the end of the course Learner will be able to

- ✓ Understand the Power system components for Renewable Energy grid integration
- ✓ Insights into the grid integration and stability issues
- ✓ Describe the application of Power electronic devices in Renewable Energy Systems
- ✓ Assess the Role of Power Systems in Wind Power integration and PV power integration
- ✓ Power Quality issues in the Power System
- ✓ Recommended IEEE/IEC/BIS standards in Power Systems

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	2	3	3	2	3	3	2	1	2	3	3	3	1	3
2	2	3	3	3	3	3	3	1	3	3	3	3	3	3
3	3	3	2	2	2	3	1	-	2	3	2	3	2	3
4	3	3	2	3	3	3	3	1	3	3	3	3	3	3
5	3	3	2	3	3	3	3	2	3	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPC1202	Waste to Energy	4	4	0	0	40	60	100

Course Objectives:

CO1 : Characterize the solid / liquid waste
CO2 : Evaluate the performance bio chemical conversion technologies
CO3 : Elucidate the thermo-chemical conversion technologies
CO4 : Design of Small Scale Waste to Energy System
CO5 : Apply waste to energy conversion techniques for sustainable development

Cognitive Level:

K1 : Understanding various terminologies in bio and thermo-chemical conversion
K2 : Analysis of Waste Treatment techniques
K3 : Sizing of Biogas plants and Gasifiers
K4 : Analysis of Supply Chain issues in Waste Management
K5 : Design of Waste Management Strategy for Smart Cities

Unit I

Solid Waste -Definitions: Sources, types, compositions; Properties of Solid Waste; Municipal Solid Waste: Physical, chemical and biological property; Collection, transfer stations; Waste minimization and recycling of municipal waste

Landfill method of solid waste disposal; Landfill classification; Types, methods & siting consideration; Layout & preliminary design of landfills: Composition, characteristics, generation; Design of Sanitary Land fill - Movement and control of landfill leachate &gases; Environmental monitoring system for landfill gases. - Gas Recovery – Applications

Unit II

Waste Treatment & Disposal Size Reduction: incineration; Furnace type & design; Types of Incinerators – Fuel Economy - Medical /Pharmaceutical waste / Hazardous waste / Nuclear Waste incineration.; Environmental impacts; Measures of mitigate environmental effects due to incineration;

Unit III

Energy Generation From Waste Types: Biochemical Conversion: Sources of energy generation, Industrial waste, agro residues; Anaerobic Digestion: Biogas production; Determination of BOD, DO, COD, TOC, & Organic loading, Aerobic & Anaerobic treatments – types of digester – factors affecting bio digestion - Activated sludge process. Methods of treatment and recovery from the in industrial waste water – Case Studies in sugar, distillery, dairy, pulp and paper mill, fertilizer, tanning, steel industry, textile, petroleum refining, chemical and power plant.

Unit IV

Rural applications of biomass –Combustion - Chulas - improved Chulas- Biomass – Physical - Chemical composition – properties of biomass –TGA – DSC characterization – Ash Characterization - Preparation of biomass – Size reduction – Briquetting of loose biomass-

Briquetting machine - Co combustion – Fluidized bed combustion Perfect, complete and incomplete combustion - stoichiometric air requirement for bio fuels - equivalence ratio

Unit V

Thermo-chemical Conversion -Basic aspects of biomass combustion - heat of combustion - different types of grates -Gasification - Fixed and Fluidized bed gasifier – Factors affecting Gasification - dual fueling in IC engines – 100 % Gas Engines – engine characteristics on gas mode – gas cooling and cleaning systems -Gasification technologies for the selected waste like Rice Husk, Coir pith, Bagasse, Poultry litter etc., - Pyrolysis – Char Characteristics Classification - process governing parameters – Typical yield rates. Carbonization Techniques – merits of carbonized fuels

Text Book

1. Parker, Colin, & Roberts, *Energy from Waste - An Evaluation of ConversionTechnologies*, Elsevier Applied Science, London, 1985
2. Shah, Kanti L., *Basics of Solid & Hazardous Waste Management Technology*, Prentice Hall, 2000

References:

1. Manoj Datta, *Waste Disposal in Engineered Landfills*, Narosa Publishing House, 1997
2. Rich, Gerald et.al., *Hazardous Waste Management Technology*, Podvan Publishers, 1987
3. Bhide AD., Sundaresan BB, Solid *Waste Management in Developing Countries*, INSDOC, New Delhi,1983.

Course Outcomes

At the end of the course learner will be able to

- ✓ Predict the best suited method for solid waste disposal.
- ✓ Select and assess various waste treatment processes.
- ✓ Develop ideas in the context of generating energy from various wastes.
- ✓ Characterize the biomass and its application in rural area for fulfilling energy demands.
- ✓ Analyze the Gasification process for various biomass wastes.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	2	2	1	3	2	3	3	2	2	3	3	2	2	2
2	2	3	2	3	2	3	3	2	3	3	3	3	3	3
3	2	3	2	3	2	3	3	2	3	3	3	3	3	3
4	3	3	3	3	2	3	3	3	3	3	3	3	3	3
5	2	3	3	3	1	3	3	1	3	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD1201	Artificial Intelligence in Renewable Energy Technologies	3	4	0	0	40	60	100

Course Objectives:

CO1 : Differentiate between Algorithmic based methods and knowledge based methods
CO2 : Use the soft computing techniques for renewable power system problems
CO3 : Use appropriate AI framework for solving renewable power system problems
CO4 : Application of AI techniques in solar, wind and bio systems
CO5 : Application ofFuzzy Logic Controller to Renewable power system

Cognitive Level:

K1 : Understanding the various Artificial intelligence techniques in Renewable systems
K2 : Application of AI Principles in renewable power generation
K3 : AI based optimization of renewable power system
K4 : Fuzzy logic Controller design and installation in renewable energy systems
K5 : Design of Fuzzy logic based Applications in renewable energy systems

UNIT-I: INTRODUCTION:

Artificial Neural Networks (ANN) – definition and fundamental concepts – Biological neural networks – Artificial neuron – activation functions – setting of weights – typical architectures – biases and thresholds – learning/training laws and algorithms. Perceptron – architectures, ADALINE and MADLINE – linear separability- XOR function. Application of ANN in Renewable Energy Systems.

UNIT-II: FUNDAMENTALS OF SOFT COMPUTING TECHNIQUES:

Definition-Classification of optimization problems- Unconstrained and Constrained optimization Optimality conditions- Introduction to intelligent systems- Soft computing techniques- Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Single solution based and population based algorithms in renewable energy systems– Exploitation and exploration in population based algorithms - Application in Renewable Energy Systems.

UNIT-III: CLASSICAL AND FUZZY SETS:

Introduction to classical sets- properties, Operations and relations; Fuzzy sets, Membership, Operations, Properties, Fuzzy relations, Cardinalities, Membership functions in the renewable energy system.

UNIT-IV: FUZZY LOGIC CONTROLLER (FLC):

Fuzzy logic system components in solar, wind, Bio energy conversion system: Fuzzification, Inference engine (development of rule base and decision making system), De-fuzzification to crisp sets- De-fuzzification methods in renewable energy systems.

UNIT-V: APPLICATIONS OF ANN AND FLC:

Applications of ANN- Solar energy forecasting- Wind energy power generation – Biogas generation prediction, Load flow, Economic load dispatch, Load forecasting, PWM solar charge controllers, selected harmonic elimination in renewable power penetration- Applications of FLC- Load frequency control of renewable grid- Speed control of solar water pumping.

Text Books

1. Neural Networks, Fuzzy logic, Genetic algorithms: synthesis and applications by Rajasekharan and pai – PHI Publication.
2. Fuzzy logic with Fuzzy Applications – T.J Ross – Mc Graw Hill Inc, 1997.

References

1. Neural Networks: A comprehensive Foundation – Simon Haykins, Pearson Edition, 2003.
2. Zimmermann, H.J., „Fuzzy set theory and its applications", Allied publishers limited, Madras, 2001
3. Yegnanarayana B, "Artificial Neural Networks", Prentice hall of India Private Ltd., New Delhi, 1999.
4. Zurada, J.M., „Introduction to Artificial Neural Systems", Jaico publishing house, Bombay, 1992.
5. David Goldberg, „Genetic Algorithms in Search, Optimization and Machine Learning", Pearson Education, 2007.
6. N P Padhy, „Artificial Intelligence and Intelligent Systems", Oxford University Press, 2005.

Course Outcomes

At the end of the course learner will be able to

- ✓ Establish AI Techniques in Renewable Energy Systems
- ✓ Describe the various AI based control for renewable power generation technologies
- ✓ Evaluate the Fuzzy logic based renewable energy projects
- ✓ Identify and analysis the fuzzy logic controller for renewable energy applications.
- ✓ Gain knowledge about ANN and FLC

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	2	2	1	3	2	3	3	3	3	2	3	2	3	3
2	3	3	1	3	3	3	3	2	3	3	3	3	3	3
3	2	2	1	2	2	3	3	2	2	3	3	2	2	3
4	2	3	2	3	3	3	3	2	3	3	3	3	2	3
5	2	3	2	2	2	3	3	3	3	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD1202	Energy Forecasting and Project Management	3	4	0	0	40	60	100

Course Objectives:

CO1 : To understand about National energy scenario.
CO2 : To predict the energy demand using various forecasting models.
CO3 : To develop an optimization model for the effective utilization of energy sources.
CO4: To know the procedure to the write the project proposal.
CO5: To know the energy policies in the country.

UNIT – I

Role of energy in economic development and social transformation: Energy & GDP, GNP and itsdynamics - Energy Sources and Overall Energy demand and Availability - Energy Consumptionin various sectors and its changing pattern -Status of Nuclear and Renewable Energy: PresentStatus and future promise.

UNIT – II

Forecasting Techniques - Regression Analysis - Double Moving Average - Double Experimental
Smoothing - Triple Exponential Smoothing – ARIMA model- Validation techniques – Qualitativeforecasting – Delphi technique - Concept of Neural Net Works.

UNIT – III

Principles of Optimization - Formulation of Objective Function - Constraints - Multi Objective Optimization – Mathematical Optimization Software – Development of Energy OptimizationModel - Development of Scenarios – Sensitivity Analysis - Concept of Fuzzy Logic.

UNIT – IV

Project Preparation – Feasibility Study – Detailed Project Report - Project Appraisal – Social-costbenefit Analysis - Project Cost Estimation – Project Risk Analysis - Project Financing – FinancialEvaluation.

UNIT – V

National & State Level Energy Issues - National & State Energy Policy - Energy Security - National solar mission - state solar energy policy - Framework of Central Electricity Authority (CEA), Central & States Electricity Regulatory Commissions (CERC & ERCs)-Costing.

Course Outcomes:

Upon completion of this course, the students will be able to:

- ✓ Have knowledge in the National energy scenario.
- ✓ Do Energy prediction using various forecasting techniques.
- ✓ Develop optimization model for energy planning.
- ✓ Capable of writing project proposals.
- ✓ Understand the National and state energy policies.

Text Book:

1. Armstrong J.Scott (ed.), Principles of forecasting: a hand book for researchers and Practitioners, Norwell, Massachusetts: Kluwer Academic Publishers.2001.
2. DhandapaniAlagiri, Energy Security in India Current Scenario, The ICFAI University Press, 2006.

References:

1. Fred Luthans, Brett C. Luthan, Kyle W. Luthans, Organisational Behaviour: An Evidence-Based Approach, Information Age Publishing; 13 edition, 2015
2. Spyros G. Makridakis, Steven C. Wheelwright, Rob J. Hyndman, Forecasting: Methods and Applications, 4th Edition, ISBN: 978-0-471-53233-0, 2003
3. Yang X.S., Introduction to mathematical optimization: From linear programming to Metaheuristics, Cambridge, Int. Science Publishing, 2008

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	-	2	2	-	-	2	3	3	3	3	-	2
2	3	3	-	2	2	-	-	2	3	3	3	3	-	2
3	2	3	-	3	2	3	3	3	3	3	3	3	2	2
4	2	2	1	3	1	3	3	3	3	3	3	2	2	3
5	-	3	-	3	-	2	3	3	3	3	3	2	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD1203	Modeling and Analysis of Energy Systems	3	4	0	0	40	60	100

Course Objectives:

CO1 : Able to use relevant tools and model for energy engineering in view of Proposing the most efficient energy systems mix
CO2 : Model different types of renewable energy mix for optimum usage
CO3 : Analyze Demand Forecasting and Modeling of Energy System
CO4 : Understand role of renewable in demand increase
CO5 : Study the financing model of RE Projects

Cognitive Level:

K1 : Understanding various terminologies of Energy Modeling and Management
K2 : Analysis of Energy Demand Modeling
K3 : Interpret Energy modeling with RE integration
K4 : Analysis of forecasting techniques
K5 : Design and Cost Economics analysis of RE project management system

Unit I

Overview of technologies and conventional methods of energy conversion, Workable and optimum systems, Steps in arriving at a workable system, Creativity in concept selection

Unit II

Mathematical modeling, Exponential forms- Method of least squares - Counter flow heat exchanger, Evaporators and Condensers, Effectiveness, NTU, Pressure drop and pumping Power

Unit III

Classes of simulation, flow diagrams, Sequential and simultaneous calculations, Newton-Raphson method- Optimization procedure, mathematical statement of the problem

Unit IV

The Lagrange multiplier equations, Sensitivity coefficients- Single variable – Exhaustive, Dichotomous and Fibonacci, Multivariable unconstrained - Lattice, Univariable and Steepestascent

Unit V

Dynamic Programming-Geometric Programming-Linear Programming- Linear regression analysis, Internal energy and enthalpy, Pressure temperature relationship at saturated conditions

Text Book

1. W.F. Stoecker: “Design of Thermal Systems”, 3rd Ed., McGraw Hill, 1989.
2. B.K.Hodge: “Analysis and Design of Thermal Systems”, Prentice Hall Inc., 1990.

3. M.Munasinghe and P.Meier *Energy Policy Analysis and Modeling*,CambridgeUniversity Press 1993
4. W.A.Donnelly *The Econometrics of Energy Demand: A Survey of Applications*, New York.1987
5. S.Pindyck and Daniel L.Rubinfeld *Econometrics Models and Economic Forecasts, 3rd edition* MC Graw -Hill, New York 1990

References:

1. UN-ESCAP *Sectoral Energy Demand Studies: Application of the END-USE Approach to Asian Countries*, New York 1991
2. UN-ESCAP *Guide Book on Energy -Environment Planning in Developing Countries: Methodological Guide on Economic Sustainability and Environmental Betterment Through Energy Savings and Fuel Switching in Developing Countries*, New York1996
3. S.Makridakis,*Forecasting Methods and Applications.* Wiley 1983

Course Outcomes

At the end of the course learner will be able to

- ✓ Identify and select the effective energy modelling with interpreting the economics and investment planning.
- ✓ Calculate the energy demand and customize the best suited methods /option.
- ✓ Interpret the data and compare the various renewable energy options along with energy conservation technologies.
- ✓ Select appropriate project evaluation technique and plan the methodology of evaluation.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	3	3	3	3	2	1	3	3	3	3	2	3
2	3	3	2	3	3	3	2	1	3	3	3	3	2	3
3	3	2	2	3	2	3	3	2	3	3	3	3	2	3
4	3	3	2	3	2	3	3	2	3	3	3	3	3	3
5	3	3	2	3	3	3	3	2	3	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD1204	**Big Data Analytics for Renewable Energy System**	3	4	0	0	40	60	100

Course Objectives:

To understand the basics of business analytics and its life cycle.
To gain knowledge about fundamental business analytics.
To learn modeling for uncertainty and statistical inference.
To understand analytics using Hadoop and Map Reduce frameworks.
To acquire insight on other analytical frameworks.

Cognitive Level:

K1 : Understanding various terminologies data analysis
K2 : Performance of uncertainty analysis
K3 : Calculate the statistical parameters
K4 : Renewable Data analysis using Numerical Methods
K5 : Design and optimize the performance of Renewable Energy system using Numerical Technique

UNIT I

Introduction – Drivers for Business Analytics – Applications of Business Analytics: Marketing and Sales, Human Resource, Healthcare, Product Design, Service Design, Customer Service and Support – Skills Required for a Business Analyst – Framework for Business Analytics Life Cycle for Business Analytics Process.

UNIT II

Descriptive Statistics – Using Data – Types of Data – Data Distribution Metrics: Frequency, Mean, Median, Mode, Range, Variance, Standard Deviation, Percentile, Quartile, z-Score, Covariance, Correlation – Data Visualization: Tables, Charts, Line Charts, Bar and Column Chart, Bubble Chart, Heat Map – Data Dashboards.

UNIT III

Modeling Uncertainty: Events and Probabilities – Conditional Probability – Random Variables – Discrete Probability Distributions – Continuous Probability Distribution – Statistical Inference: Data Sampling – Selecting a Sample – Point Estimation – Sampling Distributions – Interval Estimation – Hypothesis Testing.

UNIT IV

Introducing Hadoop – RDBMS versus Hadoop – Hadoop Overview – HDFS (Hadoop Distributed File System) – Processing Data with Hadoop – Introduction to Map Reduce – Features of Map Reduce – Algorithms Using Map-Reduce: Matrix-Vector Multiplication, Relational Algebra Operations, Grouping and Aggregation – Extensions to Map Reduce.

UNIT V

Overview of Application development Languages for Hadoop – Pig Latin – Hive – Hive Query Language (HQL) – Introduction to Pentaho, JAQL – Introduction to Apache: Sqoop, Drill and

Spark, Cloudera Impala – Introduction to NoSQL Databases – Hbase and MongoDB.

Text Books:

1. Vignesh Prajapati, “Big Data Analytics with R and Hadoop”, Packt Publishing, 2013.
2. Umesh R Hodeghatta, Umesha Nayak, “Business Analytics Using R – A Practical Approach”, Apress, 2017.

REFERENCES:

1. Anand Rajaraman, Jeffrey David Ullman, “Mining of Massive Datasets”, Cambridge University Press, 2012.
2. Jeffrey D. Camm, James J. Cochran, Michael J. Fry, Jeffrey W. Ohlmann, David R. Anderson, “Essentials of Business Analytics”, Cengage Learning, second Edition, 2016. 5. U. Dinesh Kumar, “Business Analytics: The Science of Data-Driven Decision Making”, Wiley, 2017.
3. A. Ohri, “R for Business Analytics”, Springer, 2012
4. Rui Miguel Forte, “Mastering Predictive Analytics with R”, Packt Publication, 2015.

Course Outcomes:

On completion of the course, the student will be able to:

- ✓ Identify the real world business problems and model with analytical solutions.
- ✓ Solve analytical problem with relevant mathematics background knowledge.
- ✓ Convert any real world decision making problem to hypothesis and apply suitable statistical testing.
- ✓ Write and Demonstrate simple applications involving analytics using Hadoop and Map Reduce
- ✓ Use open source frameworks for modelling and storing data
- ✓ Apply suitable visualization technique using R for visualizing voluminous data.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	2	2	2	3	3	3	3	3	3	3	3	2	2	3
2	2	2	2	3	3	3	2	1	3	3	3	2	2	3
3	3	2	2	3	3	2	2	2	2	3	3	3	2	3
4	3	3	3	3	3	2	3	2	2	3	3	3	3	3
5	3	3	3	3	3	2	3	2	2	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPC1203	Waste to Energy Laboratory	3	0	0	4	60	40	100

Course Objectives:

CO1 : Study the characteristics of wastes
CO2 : Understand supply chain issues in Waste Management
CO3 : Performance evaluation of bio chemical conversion process
CO4 : Elucidate the thermo chemical energy conversion devices performance
CO5 : Explore the biodiesel potential

Cognitive Level:

K3 : Calculate the efficiency of bio chemical thermochemical conversion system
K4 : Performance analysis of bio energy gadgets
K5 : Design and optimize the performance of biogas and gasifiers

1. Proximate analysis of solid wastes
2. Calorific value of solid wastes
3. Combustion characteristics of solid wastes
4. Study of Composting of solid wastes
5. Estimation of energy recovery potential of solid wastes
6. Study of refuse derived fuel (RDF)
7. Estimation of BOD, DO level in effluent
8. Estimation of COD level in effluent
9. Evaluation of Fixed Dome biogas plant
10. Evaluation of Floating Drum biogas plant
11. Performance analysis of gasifier
12. Performance analysis various wood stoves
13. Estimation of Calorific Value of Gaseous fuels
14. Characteristics of Fuel Cell
15. Analysis of Non Edible oil as alternate energy source

Course Outcomes

At the end of this course learner will be able to,
Evaluate the performance of

- ✓ Biochemical Conversion technologies
- ✓ Thermochemical conversion technologies
- ✓ Alternate Energy Sources

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	2	2	3	2	3	3	3	3	3	3	3	3	-	3
2	2	3	3	2	3	3	3	2	3	3	3	3	-	3
3	3	3	3	3	3	3	3	2	3	3	3	3	-	3
4	3	3	3	3	3	3	3	2	3	3	3	3	-	3
5	2	2	2	3	3	3	3	2	3	3	3	3	2	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPE1201	Energy Auditing of MSMEs (Field Visit)	2	0	0	4	30	20	50

Course Objectives:

CO1 : Study the energy consumption pattern of MSMEs
CO2 : Carryout the energy analysis of MSMEs
CO3 : Analyze the data on thermal and electrical utilities of MSME
CO4 : Explore the energy conservation steps in MSMEs
CO5 : Prepare the Energy Auditing report

Cognitive Level:

K3 : Calculate the efficiency of thermal and electrical utilities of MSME
K4 : Performance analysis of MSME
K5 : Energy Auditing Report Preparation of MSME

CFA:

- ✓ Energy Auditing, Energy Conservation Potential Identification - 15 marks
- ✓ Energy Audit Report Preparation - 15 marks

ESE:

Seminar Presentation - 10 marks
Viva-Voce - 120 marks

Course Outcomes

At the end of the course learner will be able to
Get exposure in

- ✓ MSMEs Operation
- ✓ Energy Auditing of MSMEs
- ✓ Energy Conservation Potential

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	3	3	3	3	3	3	3	3	3	3	1	3
2	3	3	3	3	3	3	3	3	3	3	3	3	1	3
3	2	2	2	3	3	3	3	3	3	3	3	3	1	3
4	2	2	2	3	3	3	3	3	3	3	3	3	1	3
5	2	2	2	3	3	3	3	3	3	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPC1204	Simulation and Analysis of Renewable Energy Sources and Devices Laboratory	3	0	0	4	0	50	50

Course Objectives:

CO1: Enable students to verify Kirchoff's Current and Voltage Laws and analyze rectifier circuits using MATLAB/SIMULINK.

CO2: Teach students to simulate and evaluate the I-V and P-V characteristics of photovoltaic modules under various conditions using MATLAB/SIMULINK.

CO3: Equip students with proficiency in using MATLAB/SIMULINK, Google Earth Pro, Windographer, Solar Pro, PVSyst, PVSOL, TSOL, and AutoCAD for renewable energy system simulations and analysis

CO4: Provide students with the knowledge to simulate and analyze wind turbine operational characteristics and assess wind potential using appropriate software.

CO5: Prepare students to design, simulate, and analyze standalone and grid-connected solar PV systems, hybrid power systems, and solar water heaters, and create site plans and single-line diagrams using advanced software tools.

Cognitive Level

K3: Design, Develop and Modelling of PV Systems

K4: Analyzing the performance of Simulated PV systems

K5: Compare, Evaluate and Decision making in the installation of PV plants based on design and analysis.

1. Verification of Kirchoff's Current & Voltage Laws using MATLAB/ SIMULINK
2. Study of working of Half-wave and Full-wave Bridge Rectifier using MATLAB/ SIMULINK
3. The I-V and P-V characteristics of PV module using MATLAB/ SIMULINK
4. Effect of Solar Irradiance & Temperature on the I-V and P-V Characteristics of the Solar PV Array using MATLAB/ SIMULINK
5. Experiment on a Solar PV panel system with a shadowing effect and bypass diode using MATLAB/ SIMULINK
6. Evaluation of Pitch Control – Cut-in Speed in Wind Turbine using MATLAB/ SIMULINK.
7. Evaluation of Cut-off Speed using MATLAB/ SIMULINK.
8. Simulation Study of Hybrid (Solar–Wind) Power System Using MATLAB/ SIMULINK.
9. Micrositing of the location in the Given Area Using Google Earth Pro.

10. Analysis of Wind Potential in the Given Area Using Windographer.
11. Design & Analysis of standalone 1kWp Systems using Solar Pro.
12. Design & Analysis of Grid-connected 1kWp Systems using Solar Pro.
13. Design & Analysis of standalone rooftop 1kWp Systems using PVSyst.
14. Design & Analysis of Grid-connected 1kWp Systems using PVSyst.
15. Design & Analysis of standalone rooftop 1kWp Systems using PV*SOL.
16. Design & Analysis of Grid-connected 1kWp Systems using PV*SOL.
17. Design & Analysis of Solar Water Heater using T*SOL.
18. Site Plan design using AutoCAD
19. PV Module Array Design Using AutoCAD
20. Single Line Diagram of the PV Project using Auto CAD

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	3	3	3	3	3	3	3	3	3	3	3	3
2	3	3	3	3	3	3	3	3	3	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPC1205	Universal Human Values and Professional Ethics	2	0	0	4	50	0	50

Course Objective:

CO1 : Development of a holistic perspective based on self-exploration about themselves (Human being), family, society and nature/existence.

CO2 : Understanding (or developing clarity) of the harmony in the human being, Family, society and nature/existence

CO3 : Strengthening of self-reflection.

CO4 : Development of commitment and courage to act.

Unit I

Course Introduction - Need, Basic Guidelines, Content and Process for ValueEducation. Purpose and motivation for the course, recapitulation from Universal HumanValues. Self-Exploration–what is it? - Its content and process; 'Natural Acceptance'and Experiential Validation- as the process for self-exploration Continuous Happiness and Prosperity- A look at basic Human Aspirations Right understanding, Relationship and Physical Facility- the basicrequirements for fulfilment of aspirations of every human being with their correctPriority Understanding Happiness and Prosperity correctly- A critical appraisal of thecurrent scenario Method to fulfil the above human aspirations: understanding and living inharmony at various levels.Include practice sessions to discuss natural acceptance in human being as theinnate acceptance for living with responsibility (living in relationship, harmonyand co-existence) rather than as arbitrariness in choice based on liking-disliking

Unit II:

Understanding Harmony in the Human Being - Harmony in Myself! Understanding human being as a co-existence of the sentient 'I' and thematerial 'Body'Understanding the needs of Self ('I') and 'Body' - happiness and physical facility Understanding the Body as an instrument of 'I' (I being the doer, seer andenjoyer). Understanding the characteristics and activities of 'I' and harmony in 'I'. Understanding the harmony of I with the Body: Sanyam and Health; correct Appraisal of Physical needs, meaning of Prosperity in detail. Programs to ensure Sanyam and Health.Include practice sessions to discuss the role others have played in makingmaterial goods available to me. Identifying from one's own life. Differentiatebetween prosperity and accumulation. Discuss program for ensuring health vsdealing with disease

Unit III:

Understanding Harmony in the Family and Society- Harmony in Human Relationship Understanding values in human-human relationship; meaning of Justice (nineuniversal values in relationships) and program for its fulfilment to ensure mutualhappiness; Trust and Respect as the foundational values of relationshipUnderstanding the meaning of Trust; Difference between intention andCompetence Understanding the meaning of Respect, Difference between respect anddifferentiation; the other salient values in relationship Understanding the harmony in the society (society being an extension offamily): Resolution, Prosperity, fearlessness (trust) and co-existence ascomprehensive Human Goals Visualizing a universal harmonious order in

society- Undivided Society,Universal Order- from family to world family.Include practice sessions to reflect on relationships in family, hostel and instituteas extended family, real life examples, teacher-student relationship, goal ofeducation etc. Gratitude as a universal value in relationships. Discuss withscenarios. Elicit examples from students' lives

Unit IV

Understanding Harmony in the Nature and Existence - Whole existence asCoexistence18. Understanding the harmony in the NatureInterconnectedness and mutual fulfilment among the four orders of nature recyclability and self-regulation in natureUnderstanding Existence as Co-existence of mutually interacting units in all-pervasivespaceHolistic perception of harmony at all levels of existence.Include practice sessions to discuss human being as cause of imbalance innature (film "Home" can be used), pollution, depletion of resources and role oftechnology etc.

Unit V: Implications of the above Holistic Understanding of Harmony onProfessional EthicsNatural acceptance of human values Definitiveness of Ethical Human Conduct. Basis for Humanistic Education, Humanistic Constitution and HumanisticUniversal Order Competence in professional ethics: a. Ability to utilize the professionalcompetence for augmenting universal human order b. Ability to identify the scopeand characteristics of people friendly and eco-friendly production systems, c.Ability to identify and develop appropriate technologies and managementpatterns for above production systems.Case studies of typical holistic technologies, management models andproduction systemsStrategy for transition from the present state to Universal Human Order: a. Atthe level of individual: as socially and ecologically responsible engineers,technologists and managers b. At the level of society: as mutually enrichinginstitutions and organizations

Text Book

1. Human Values and Professional Ethics by R Gaur, R Sangal, G P Bagaria,Excel Books,New Delhi, 2010

References

1. Jeevan Vidya: Ek Parichaya, A Nagaraj, Jeevan Vidya Prakashan, Amarkantak,1999.
2. Human Values, A.N. Tripathi, New Age Intl. Publishers, New Delhi, 2004.
3. The Story of Stuff (Book).
4. The Story of My Experiments with Truth - by Mohandas Karamchand Gandhi
5. Small is Beautiful - E. F Schumacher.
6. Slow is Beautiful - Cecile Andrews
7. Economy of Permanence - J C Kumarappa
8. Bharat Mein Angreji Raj - PanditSunderlal
9. Rediscovering India - by Dharampal
10. Hind Swaraj or Indian Home Rule - by Mohandas K. Gandhi
11. India Wins Freedom - Maulana Abdul Kalam Azad
12. Vivekananda - Romain Rolland (English)
13. Gandhi - Romain Rolland (English)

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24ENGP00C1	Communication & Soft Skills	2	2	0	0	50	0	50

Course Objectives:

- ✓ To impart effective communication
- ✓ To inculcate the soft skill

UNIT I

- Basics of Communication
- Barriers to Communication

UNIT II

- Communication and Language Skills
- Communicating in a Global Language

UNIT III

- Resumes and Cover Letters
- Group Discussions

UNIT IV

- Business communication
- Intercultural Communication

UNIT V

- Professional Communication
- Interviews

Textbook:

Krishnaswamy, Dhariwal and Krishnaswamy. *Mastering Communication Skills and Soft Skills*. Blomsbury, 2015.

Course Outcomes

i). To develop inter personal skills and be an effective goal oriented team player.
ii). To develop professionals with idealistic, practical and moral values.
iii). To develop communication and problem solving skills.
Iv). To re-engineer attitude and understand its influence on behavior.

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
Non-Credit Value-Added Course	Inter-Departmental Courses	-	2	0	0	50	0	50

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPC2101	Summer Internship	2	0	0	0	0	50	50

Course Objective

CO1 : To sensitize students to the nuances of a work place by assigning time-bound projects in a company / R&D organization or NGO working on Renewable Energy

Cognitive Level:

K3 : Data / Survey questionnaire preparation
K4 : Data Analysis
K5 : Interpretation of data and report preparation

Student should undergo an inplant training in a process / product industry / NGO in energy related area or should undergo an energy auditing in any rural industries and submit a report along with certificate (details of the training undergone) from the industry where he / she undergone the training for a period of 30 calendar days. Student should present a seminar about the energy saving potential / case study of the industry or energy planning. Evaluation is based on the report, Seminar Performance and *viva voce*.

ESE:

Report - 25 marks
Seminar &Viva-Voce - 25 marks

Course Outcomes

At the end of the course learner will be able to
Get exposure in

- ✓ Renewable Energy Industrial Exposure
- ✓ Rural Industries Energy Auditing
- ✓ Role of NGO's in Energy planning

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	3	3	3	3	3	3	3	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD2101	Green Hydrogen	3	4	0	0	40	60	100

Course Objectives:

CO1 :Inculcate the Sustainability in Rural Electrification through green hydrogen mix
CO2 :Understand the Schemes and Policies of Govt. of India
CO3 :Know the different technologies including hydrogen for Rural Electrification
CO4 :Analyze the financial viability and cost-benefit analysis
CO5 :Able to prepare the techno-commercial report on Rural Electrification

Cognitive Level:

K1 :Understanding the various basics of green hydrogen
K2 :Application of green hydrogen in the rural electrification process
K3 :Interpret various economic models for green hydrogen-enabled rural microgrid
K4 :Comparative analysis of technologies of Rural Electrification
K5 :Comparison of various technologies and economics for Rural Electrification

Unit I: Introduction to Hydrogen Energy

Properties of hydrogen as fuel, Physical and chemical properties of hydrogen gas; overview of hydrogen energy utilization; Hydrogen sensing- methods of hydrogen using thermal conductivity measurements or Gas chromatography, mass spectrophotometry or laser gas analysis

Unit II: Hydrogen Production

Thermal-steam reformation, gasification, pyrolysis, thermo-chemical water splitting, nuclear thermal catalytic and partial oxidation methods; Electrochemical-electrolysis, photo-electro chemical; Biological-anaerobic digestion, fermentation, PM based electrolyser

Unit III: Hydrogen Storage

Hydrogen separation and purification-pressure swing adsorption, solvent based adsorption, membrane separation, cryogenic separation; Hydrogen storage-compressed storage, liquid state storage, solid state storage, different materials for storage-metal hydrides, high surface area materials, complex and chemical hydrides; hydrogen storage system-design and material aspects

Unit IV: Fuel Cells

History, principle, working of fuel cells, thermodynamics and kinetics of fuel cell process; concept of electrochemical potential and Nernst equation, performance and evaluation of fuel cell; Comparison of battery and fuel cells; Types of fuel cell-AFC, PFAC, SOFC, DMFC, PEMFC and Microbial fuel cell, relative merits and demerits

Unit V: Rural Electrification

Role of Electricity in Rural Development - Village Electrification in India - Current Status-Rural Electrification – Indian Perspective - Genesis of India’s RE Programme- Major RE Programmes - Pradhan Mantri Gramodaya Yojana (PMGY) - Accelerated Rural Electrification Programme (AREP) – Recent Policy And Frame Work Of Re Programme - Characteristics of

RE Programme - Rural Electrification Models - Potential electrification models- Decentralized generation technologies; Economic and financial analysis of stand-alone electrification projects– Fixed and Variable Cost – Interest Rate – Simple Payback - Discounted Cash Flow Methods - Net Present Value Method - Internal rate of return method- Profitability index - Factors Affecting Analysis Real value - Project Management - Project Definition and Scope - Technical Design – Financing – Contracting - Implementation -Performance Monitoring

Textbooks/Suggested Readings:

1. Sorenson B, Hydrogen and Fuel cells, Elsevier, Academic Press, USA
2. Yurum Yuda, Hydrogen Energy Systems, NATO ASI Series, London
3. Baker BS, Hydrogen Fuel cell Technology, Academic Press, New York
4. O'Hayre R, Cha S, Colella W., Prinz F.B, Fuel Cell Fundamentals, John Willey and Sons, New York
5. Hydrogen and Fuel Cells: A comprehensive Guide Rebecca L. Busby, PennWell Books

Reference Books:

1. T. Gonen: Electric Power Distribution System Engineering, McGraw-Hill 1986.
2. M Mohan: Rural electrification for development: policy analysis and applications. Boulder : Westview Press, 1987
3. G. Saunier: Rural electrification guidebook for Asia and the Pacific, Asian Institute of Technology, 1992.
4. H. Lee Willis and W.G. Scott: Distributed Power Generation: Planning and Evaluation, Marcel Dekker, 2000.

Course Outcome :

1. Application of renewable energy technologies for rural electrification
2. Evaluate the performance of fuel cells under different operating conditions
3. Select appropriate fuel cell technology for a given application
4. Design and develop suitable hydrogen systems to be used along with the fuel cell system for sustainable rural electrification

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	2	2	2	3	3	3	3	2	3	3	3	3	2	3
2	2	2	2	3	3	3	3	3	3	3	3	3	2	3
3	2	2	2	3	3	3	3	3	3	3	3	3	2	3
4	2	2	2	3	3	3	3	3	3	3	3	3	2	3
5	2	2	2	3	3	3	3	3	3	3	3	3	2	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD2102	Rural Microgrids	3	4	0	0	40	60	100

Course Objectives:

CO1 : Understand the main issues of smart grid development
CO2 : Know the recent technologies that underpin for the smart grid development
CO3 : Able to analyze the economic analysis of Smart Grid
CO4 : Understand grid integration issues on smart grid
CO5 : Compare AC/ DC micro girds

Cognitive Level:

K1 : Understanding various terminologies on smart grid
K2 : Analysis of IEC / IEEE Standards
K3 : Interpret various economics models
K4 : Comparative analysis of Distribution Management system
K5 : Design and Analysis of AC/ DC Smart Grids

Unit I

Introduction –driving the move towards Smart Grids globally and in India Smart Grid. Overview of how Indian power market is organized, operated and challenges being faced. Overview of how the Indian GENERATION, TRANSMISSION and DISTRIBUTION business is operated and controlled and some of the challenges being faced. How software can manage generation and optimize generator performance, Software to support integration of renewables, System planning & condition monitoring based maintenance, Forecasting & basic trading, Demand response, Performance management

Unit II

Overview of power sector communications, Generic model of communication network needed for Smart-grid, Introduction to different communication technologies available in the market (Latest standards. Emphasis on importance of inoperability and standardization of communication protocols), Matrix of different technologies against the smart-grid communication needs in a given utility environment, AMI, AMR & MDA: How it works and how it will help to; reduce peaks manage networks more efficiently and contribute towards smarter grids, Communication Standards IEC6150, Wide Area Situation Awareness (WASA), Network stability and Phasor Measurement Unit (PMU), 6Automation and Integration of Distributed Generation / Renewable Energy, Automation and Micro-grids

Unit III

Distribution Management Systems (DMS) and Meter Data Management (MDM) are improving energy efficiency and security of supply in Distribution Systems, Overview of Power Electronics in

Electrical T&D Systems, Power Electronics in emerging Smart Grids, Transmission (DC Super Grids) , Distribution (PE facilitating the integration of, (Distributed Generation, Renewables, Micro grids, Virtual Power Plants (VPP), Storage, Fault Current Limitation, Power Electronics, Super Conducting and Magnetic types)

Unit IV

Developing technology and systems that will enable grids to work smarter in the future: Storage: Organic and Inorganic Salts & Synthetic Heat Storage, Developing technology and systems that will enable grids to work smarter in the future (Smart Meters, Recording consumption, Advanced payback options for load-management, Communication between the utility and customer's home

(for home automation)), In-home controls, Demand Side Management (DSM).Power Trading & the India Energy Exchange : Encouraging Markets, Regulation enabling grids to work smarter in India, Project Financing: Financial Incentives to Enable Smart Grids in India, Smart Grid Economics: Making Smarter Grids Financially Viable, Planning for Smarter Grids

Unit V

Challenges faced by the Transmission System Developing technology and systems that will enable smarter transmission of bulk energy (Metering, Trading mechanisms, AC – FACTS (STATCOMs)

DC – HVDC, Fault Current Limiters), Challenges faced by the Distribution Networks :(How to be more energy efficient, stable, reliable and environmentally friendly, Reducing losses, Integration of renewables Connecting/disconnecting micro-grids and virtual power plants, manage bi-directional energy flows), Developing technology and systems that will enable smarter distribution networks (DC – MVDC, Fault Current Limiters, Others (AC/DC TXs etc.))

Text Book

1. Join Gridwise & Smartgrids groups in LinkedIn http://www.linkedin.com/
2. Sign up to Smart Grid News www.smartgridnews.com
3. US DoE Smart Grid Book
   http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages (1).pdf

References:

1. Technology enabling the transformation of India's power distribution
   http://www.infosys.com/newsroom/features/power-sector-report.pdf
2. Gridwise Alliance website http://www.gridwise.org/
3. European Union Smart Grids Technology Platform http://www.smartgrids.eu/

Course Outcomes

At the end of the course students will be able to

- ✓ Lead students towards a clear understanding and firm grasp of the basic principles of smart grid.
- ✓ Understand the structure of an electricity market in either regulated or deregulated market conditions.
- ✓ Understand how (wholesale) electricity is priced in a transmission network.
- ✓ Evaluate the trade-off between economics and reliability of an electric power system.
- ✓ Understand the impacts of renewable resources to the grid and the various issues associated with integrating such resources to the grid.
- ✓ Evaluate various investment options (e.g. generation capacities, transmission, renewable, demand-side resources, etc.) in electricity markets.
- ✓ Understand the concepts and principles of Smart Grid, technology enabling, and demand participation.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	2	2	2	3	3	3	3	2	3	3	3	3	2	3
2	2	2	2	3	3	3	3	3	3	3	3	3	2	3
3	2	2	2	3	3	3	3	3	3	3	3	3	2	3
4	2	2	2	3	3	3	3	3	3	3	3	3	3	3
5	2	2	2	3	3	3	3	3	3	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD2103	Energy Efficient Buildings	3	4	0	0	40	60	100

Course Objectives:

CO1 : Ascertain the need, opportunities and demand of green buildings
CO2 : Explore the possibility of energy efficiency on buildings
CO3 : Comparative study of green buildings on different climatic zone
CO4 : Understand cost economics and payback calculation of energy efficient buildings
CO5 : Able to compare different rating techniques of buildings

Cognitive Level:

K1 : Understanding various terminologies on green building
K2 : Analysis of ISHRA / GRIHA/ GBC Standards
K3 : Interpret various design of green buildings
K4 : Comparative analysis of conventional Vs energy efficient buildings
K5 : Design and Analysis of Solar Passive Buildings

Unit I:

Introduction to architecture; Building science and its significance; Energy management concept in building - Thermal Analysis And Design For Human Comfort - Thermal comfort; Criteria and various parameters; Psychometric chart; Thermal indices, climate and comfort zones; Concept of sol-air temperature and its significance; Calculation of instantaneous heat gain through building envelope;

Unit II:

Calculation of solar radiation on buildings; building orientation; Introduction to design of shading devices; Overhangs; Factors that effects energy use in buildings; Ventilation and its significance; Air-conditioning systems; Energy conservation techniques in air-conditioning systems

Passive Cooling And Heating Concepts - Passive heating concepts: Direct heat gain, indirect heat gain, isolated gain and sunspaces; Passive cooling concepts: Evaporative cooling, radiative cooling; Application of wind, water and earth for cooling; Shading, paints and cavity walls for cooling; Roof radiation traps; Earth air-tunnel.

Unit III:

Heat Transmission In Buildings - Surface co-efficient: air cavity, internal and external surfaces, overall thermal transmittance, wall and windows; Heat transfer due to ventilation/infiltration, internal heat transfer; solar temperature; Decrement factor; Phase lag. Design of daylighting

Unit IV:

Estimation of building loads: Steady state method, network method, numerical method, correlations; Computer packages for carrying out thermal design of buildings and predicting performance.

Bioclimatic Classification - Bioclimatic classification of India; Passive concepts appropriate for the various climatic zones in India; Typical design of selected buildings in various climatic zones; Thumb rules for design of buildings and building codes.

Unit V:
Energy Efficient Landscape Design -Modification of microclimatic through landscape element for energy conservation; Energy conservation through site selection, planning, and design; Siting and orientation – GRIHA – Certification of Green Buildings

Text Book

1. M.S.Sodha, N.K. Bansal, P.K. Bansal, A. Kumar and M.A.S. Malik, *Solar Passive Building, Science and Design*, Pergamon Press, 1986.
2. J.R. Williams, *Passive Solar Heating*, Ann Arbar Science, 1983.
3. R.W.Jones, J.D. Balcomb, C.E. Kosiewiez, G.S. Lazarus, R.D. McFarland and W.O. Wray, *Passive Solar Design Handbook, Vol. 3, Report of U.S. Department of Energy (DOE/CS-0127/3)*, 1982.

References:

1. J Krieder and A Rabi *Heating and Cooling of Buildings : Design for Efficiency*, McGraw-Hill (1994)
2. R D Brwon, T J Gillespie, *Microclimatic Landscape Design*, John Wiley & Sons, New York, 1990.
3. D.S. Lal, Sharda Pustak Bhawan, *Climatology*,Allahabad, (2003)
4. Majumder Milli, *Energy Efficient Buildings*, TERI, New Delhi 2002
5. T A Markus, E N Morris, *Building, Climate and Energy*, Spottwoode Ballantype Ltd. London, 1980.
6. Sanjay Prakash (et al.), *Solar architecture and earth construction in the NorthWest Himalaya*,Vikas, New Delhi,1991
7. Energy Research Group, CD Rom Version 2 , LIOR Ireland, *Solar Bioclimatic Architecture*,1999

Course Outcomes

At the end of the course learner will be able to

- ✓ Classify different climatic zones and comfort environment.
- ✓ Incorporate and assess various passive solar techniques in building design.
- ✓ Modeling of heat distribution in the built environment.
- ✓ Design & assess the energy efficient landscape through modification of microclimate.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	2	2	2	3	3	3	3	2	3	3	3	3	2	3
2	2	2	2	3	3	3	3	3	3	3	3	3	2	3
3	2	2	2	3	3	3	3	3	3	3	3	3	2	3
4	3	3	2	3	3	3	3	2	3	3	3	3	3	3
5	3	3	2	3	3	3	3	2	3	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD2104	Electrical Vehicles and Energy Storage	3	4	0	0	40	60	100

Course Objectives:

CO1 : Describe the fundamentals of Electric Vehicle
CO2 : Design and analysis of the Electric Vehicle
CO3 : Design and analysis of the Hybrid Electric Vehicle
CO4 : Understand the concepts of Nano grid, energy storage and management
CO5 : Study on power quality issues on Nano Grid Technologies

Cognitive Level

K1 : Identify and analyze the various classification of Electric Vehicle
K2 : Evaluate the Performance of Electric Vehicle
K3 : Calculate drive system efficiency of Electric Vehicle
K4 : Design of V2G energy systems
K5 : Performance Evaluation of Nano Grid in terms of Power Quality

UNIT-1

Basics of vehicle performance, vehicle power source characterization, transmission characteristics, and mathematical models to describe vehicle performance. Social and environmental importance of hybrid and electric vehicles

UNIT-2

Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives - Induction Motor drives - Permanent Magnet Motor drives - Switch Reluctance Motor drives, drive system efficiency. Electric traction – various topologies-Power flow-Case Study - Design of a Hybrid Electric Vehicle (HEV)

UNIT-3:

Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery - Fuel Cell - Super Capacitor- Flywheel based energy storage system - Introduction to energy management strategies - classifications, comparison of different energy management strategies, implementation issues of energy management strategies.

UNIT-4

Introduction to vehicle to Grid technologies-Embedded generation-Issues of Embedded generation-Vehicle to Grid technologies, common attributes of embedded generation, basic power conversion of solar PV system, wind electric conversion systems-Grid requirements of PV and Wind Turbine System

UNIT-5

Definition of Power Quality-Effect of Harmonics on Power System Devices-Guidelines for Harmonic Voltage and Current Limitation-Power Quality Measurement Devices- Number of Test Locations-Test Duration-Instrument Setup-Instrument Setup Guidelines-Harmonic Current Mitigation-Equipment Design-Harmonic Current Cancellation-Harmonic Filters

TEXT BOOKS:

1. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.
2. Roger C.Dugan, Mark F. McGranaghan,Surya Santoso& H.Wayne Beaty: Electrical Power Systems Quality, Tata McGraw-Hill

REFERENCES

1. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.
2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.
3. Related MOOC Courses
4. C. Sankaran : Power Quality CRC Press,2002

Course Outcomes

At the end of the course learner will be able to

- ✓ Understand the concepts of Electric vehicles
- ✓ Design the Electric Vehicle
- ✓ Evaluate the performance of Electric vehicles
- ✓ Optimize the various energy sources in Nano grid technologies (V2G)
- ✓ understating the various International Power quality standards and mitigation techniques

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	2	-	2	1	-	-	2	3	3	3	3	-	2
2	3	2	3	2	3	2	2	1	3	3	3	3	-	2
3	3	2	3	2	3	2	2	1	3	3	3	3	-	2
4	-	1	1	3	-	3	3	3	3	3	3	2	3	3
5	-	3	-	3	-	2	3	3	3	3	3	2	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD210Y	MOOC 1	2	2	0	0	50	0	50

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPD210Z	MOOC 2	2	2	0	0	50	0	50

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPE2101	Rural Energy Planning (Field Visit)	3	2	0	4	60	40	100

Course Objectives:

CO1 : Learn about the Rural Energy related issues
CO2 : Collect and analyze the village level data
CO3 : Prepare the Detailed Project Report incorporating Govt. Schemes and Policies

Cognitive Level:

K3 : Data / Survey questionnaire preparation
K4 : Data Analysis
K5 : Interpretation of data and report preparation

Group of Students (Maximum of 5 to 6) will be provided to undergo a 100% Energy related survey in a selected village panchayat and analyze the present energy consumption and thefuture energy requirement. Based on the survey report the student must submit a Detailed Project Report (DPR) incorporating all the polices and schemes of the Govt. to be implemented in the selected village which will enable to create a '*Model Energy Village'.*

CFA:

Seminar Presentation 1 - 10
Seminar Presentation 2 - 10
DPR Preparation - 40

ESE:

Report and Seminar Presentation - 20 marks
Viva-Voce - 20 marks

Course Outcomes

At the end of the course learner will be able to
Get exposure in

- ✓ Rural Energy related issues to inconformity with the Constitutional Provisions
- ✓ Planning of present and future energy requirement of village
- ✓ Govt. Schemes and polices implemented or to be implemented
- ✓ Developing evaluation indicators for the Govt. Schemes
- ✓ Detailed Project Report (DPR) preparation

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	1	1	3	3	3	3	3	3	3	3	3	3	3
2	3	2	2	3	3	3	3	3	3	3	3	3	3	3
3	3	2	2	3	3	3	3	3	3	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPM2101	Solar PV Project Management	2	2	0	0	50	0	50

Course Objectives

CO1: Understand the fundamentals of solar PV technology and the solar power sector
CO2: Develop skills in project design, scheduling, and securing necessary permits.
CO3: Conduct site surveys, demand/load analysis, and use solar design software.
CO4: Install PV system components and ensure project quality control.
CO5: Apply safety practices and comply with standards and regulations.

Unit I

Overview of Solar PV Technology: solar PV power generation technology and fundamentals of solar resource assessment, broad design of the solar PV power plant • cost of solar power plant, ground mount solar sector in India, Rooftop Solar Sector in India. Project design, sequencing, and mobilization plan; permits /approvals for construction including permission for grid connectivity, project bill of materials, and project scheduling

Unit II

Preparatory Phase: Site survey, mounting structures/options, Shadow analysis, Demand/ Load Analysis, battery backup as per grid availability, loads, and client expectation, solar design software like PV*SOL®, PVsyst; Feasibility Study Report, electrical designs for the module/ inverters and balance of system; PV System sizing and requirement

Unit III

Installation Phase: Installation of module structures and modules, installation of inverters, transformers, earthing piles, DC/ AC power protection devices, lightning arresters, and substation as per the grid codes and regulatory provisions. safety and crisis management plan for the site. overall project quality control program

Unit IV

Standards & Documentation: IS/IEC standards, thermography for defects identification, performance ratio test; documentation: warranty, performance guarantees, calibration certificates, and any other relevant documentation, development and maintenance of all logs for drawings, submittal, etc.

Unit V

Safety Practices: Personal protective equipment, hazards associated with photovoltaic installations, work safety procedures and instructions for working at height; Understand Occupational Health & Safety standards and regulations for installation of Solar PV system

Text Books

1. Gevorkian, Peter. 2011. “SOLAR POWER SYSTEM PROJECT MANAGEMENT.” Chap. 9 in Large-Scale Solar Power System Design: An Engineering Guide for Grid-Connected Solar Power Generation. 1st ed. New York: McGraw-Hill.
2. Albie Fong, Jesse Tippett . “Project Development in the Solar Industry” ISBN 9780367576615 Published June 30, 2020 by CRC Press Thapar, S.
3. Renewable Energy in India—Policy and Regulatory Framework. In Renewable Energy: Policies, Project Management and Economics: Wind and Solar Power (India); Springer: Singapore, 2024

Reference Books

1. Christopher Martell, Geoff Stapleton, Susan Neill, Frank Jackson. 2021. Solar Farms: The Earthscan Expert Guide to Design and Construction of Utility-scale Photovoltaic Systems. Routledge; 1st edition
2. Jenny Chase. 2019. Solar Power Finance Without The Jargon. World Scientific Europe Ltd
3. Angèle Reinders, Pierre Verlinden, Wilfried van Sark, Alexandre Freundlich. 2016. Photovoltaic Solar Energy: From Fundamentals to Applications. John Wiley & Sons, Ltd

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	2	-	2	1	-	-	2	3	3	3	3	-	2
2	3	2	3	2	3	2	2	1	3	3	3	3	-	2
3	3	2	3	2	3	2	2	1	3	3	3	3	-	2
4	-	1	1	3	-	3	3	3	3	3	3	2	3	3
5	-	3	-	3	-	2	3	3	3	3	3	2	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPM2102	Entrepreneurship in Green Hydrogen	2	2	0	0	50	0	50

Course Objectives

CO1: Understand the properties, production, storage, and transportation of green hydrogen, and explore its applications and entrepreneurial opportunities.

CO2: Learn about the layout and working principles of key components in a green hydrogen plant, and perform SWOT and safety analyses.

CO3: Gain knowledge of different electrolyzer types, their operation, and challenges in hydrogen storage and handling.

CO4: Develop skills to prepare detailed project reports, assess costs, and understand financing options for hydrogen production plants.

CO5: Familiarize with national policies, standards, incentives, and safety regulations related to green hydrogen.

Unit I

Introduction to Green Hydrogen Energy: Properties and characteristics of Hydrogen, Hydrogen as an energy carrier, key aspects related to production, storage, and transportation of Green Hydrogen. hydrogen economy, applications of green hydrogen in industry, transport, and power production, entrepreneurial opportunities across the Green Hydrogen Value chain, role and responsibilities of a Green Hydrogen Plant Entrepreneur.

Unit II

Green Hydrogen Plant Layout & Working: Electrical, mechanical, and civil components of Green Hydrogen plant; the overall layout of the plant: electrolyzer stack, renewable power plant, feed water supply unit, gas separator, transformer and rectifier, gas compression unit. Working principles of main components including electrolyzer stack, gas separator, power source, etc. SWOT analysis, safety aspects to be considered while preparing the layout of a hydrogen production plant

Unit III

Electrolyzer types & handling: Electrolyzer Type (PEM, AE, SOEC), Operation of PEM and AE and SOEC electrolyzer, Comparison between above electrolyzer regarding the life, cost, efficiency, electricity consumption, the process for Installation of Electrolyzer, Challenges associated with Hydrogen in storage, handling, and transportation

Unit IV

Project Report & Costs: Setting up hydrogen production plants including required registration, availing low-cost financing from Financial Institutions/Venture Capital/Banks, government subsidies, green power, free-wheeling/banking of renewable energy, etc. Detailed Project Report (DPR), lifecycle cost of hydrogen production, storage system, cash flow, annual savings, payback period, IRR, inflation, increase in fossil fuel cost, sensitivity analysis by varying costs of renewable energy, water, manpower, and such other factors, etc. O&M-related costs for the system.

Unit V

Policies, Standards & Incentives: National Green Hydrogen policy and corresponding incentives/subsidies available and procedures for availing the same, micro-entrepreneurship in the green hydrogen sector, labeling/certification for green hydrogen generators and facilitating compliance with relevant standards and regulations, Safety standards and regulations for Basic considerations for the safety of hydrogen systems

Text Books

1. Marco Alverà, 2021. The Hydrogen Revolution: A Blueprint for the Future of Clean Energy. Basic Books
2. Jeremy Rifkin, The Hydrogen Economy, Penguin Group, USA
3. Raboaca, Maria Simona, et al., editors. Advancements in Renewable Energy and Green Hydrogen. IGI Global, 2024.
4. NITI Ayog Report on "Harnessing Green Hydrogen Opportunities For Deep Decarbonisation In India". https://www.niti.gov.in/sites/default/files/2022-06/Harnessing_Green_Hydrogen_V21_DIGITAL_29062022.pdf
5. SAREP Report "Investment Landscape Of Green Hydrogen In India". https://sarepenergy.net/wp-content/uploads/2023/05/GREEN-HYDROGEN-FINAL-Version.pdf

Reference Books

1. Rebecca L. and Busby, Hydrogen and Fuel Cells: A Comprehensive Guide, Penn Well Corporation, Oklahoma
2. IRENA report on "Green hydrogen: A guide to policy making". https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Nov/IRENA_Green_hydrogen_policy_2020.pdf

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	2	-	2	1	-	-	2	3	3	3	3	-	2
2	3	2	3	2	3	2	2	1	3	3	3	3	-	2
3	3	2	3	2	3	2	2	1	3	3	3	3	-	2
4	-	1	1	3	-	3	3	3	3	3	3	2	3	3
5	-	3	-	3	-	2	3	3	3	3	3	2	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPM2103	Wind Resource Assessment and Site Survey	2	2	0	0	50	0	50

Course Objectives:

CO1 : To understand the site survey methodology and feasibility study of wind power plants from the point of Renewable Energy Site Surveyor as per NSQF

Cognitive Level:

K3 : Estimation of Wind Resource Assessment
K4 : Enhance site survey skill on wind power conversion system
K5 : Detailed wind resource assessment of wind power plant and report writing

UNIT-I:

Analyse detailed site information - analyse the daily, monthly and annual wind resource data of site to evaluate the potential for wind energy generation -ensure the collection of data on local weather conditions such as temperature range, flooding (in case of onshore), wind speed, humidity, rainfall and assess its impact on wind energy generation. -Assess the ground water availability and quality, load bearing capacities, pH levels and seismic risk -analyse the pre-site selection baseline data for project execution suitability -identify location for Power Curve test -ensure installation of meteorological mast (met mast) at site - analyse wind data collected from met mast for wind potential

UNIT-II:

Prepare a detailed survey plan of the land proposed for installation of wind power plant with elevations and topography - calculate the exact land area of the proposed site where installation is to be commenced -prepare contour map of proposed wind plant site -conduct field surveys and give site ranking -identify position of WTG, substation, transmission line, transformers, etc.

UNIT-III:

Identify accessibility of the site i.e., its connectivity to various transport mechanisms including rail, road, connecting roads etc. -ensure conducting of route survey - identify soil type and its strength -identify state/central law of land leasing and purchase

UNIT-IV:

Analyse environmental and social impact of the plant and site risk analysis -Identify local support and hindrance factors and include in the report as a special section -Identify limitations and incentives according to relevant applicable policies, regulations and procedures

UNIT-V:

Validate collected wind data from site -verify the wind potential with other resources such as NREL/ATLAS -prepare detailed site survey report using GPS/DGPS and wind data analysis software.

TEXT BOOK:

1. David A. Spera, (Editor) Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, American Society of Mechanical Engineers; (1994)
2. Mukund R. Patel, Wind and Solar Power Systems , CRC Press; (1999)

REFERENCE BOOK:

1. G.L.Johnson. Wind Energy Systems, Prentice Hall Inc, New Jersey, 1985
2. Erich Hau,Wind Turbines: Fundamentals, Technologies, Application and Economics, Springer Verlag; (2000)
3. Paul Gipe , Karen Perez, Wind Energy Basics: A Guide to Small and Micro Wind Systems, Chelsea Green Publishing Company; (1999)
4. J. F. Manwell, J. G. McGowan, A. L. Rogers, Wind Energy Explained, John Wiley & Sons; 1st edition (2002)

Course Outcomes

At the end of the course learner will be able to

- ✓ Carry out the wind site resource assessment
- ✓ Prepare site feasibility report
- ✓ Manage Wind power project lifecycle
- ✓ Entrepreneurship skills
- ✓ Maintain Personal Health & Safety at project site

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	2	2	3	3	3	3	3	3	3	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPM2104	Waste Management	2	2	0	0	50	0	50

Course Objectives:

CO1 : To understand the waste management from the point of Manager- Waste a Management as per NSDC

Cognitive Level:

K3 : Estimation of Waste Resource or Source

K4 : Enhance the market survey and operational plan creation on Waste management

K5 : Operational Management of Biomass Depot, Compost yard and Dry Waste Center

UNIT-I:

Explain different types of waste and compost - Describe the role of Manager for Waste Management - Demonstrate processes for procurement, processing and onward supply of biomass for biomass depot - Explain production management and marketing of urban waste compost - Demonstrate collection and management of dry waste focusing on plastic, paper and other waste

UNIT-II:

Identify methods of determining existing market demands- Outline primary and secondary research to identify market determinants and customer's needs - Demonstrate project growth using statistical tool and develop profiles of resulting market segments - Identify competitors in the market and assess their respective sales strategies - Formulate an operational plan - Demonstrate methods to identify key resources, suppliers of different waste stream based on the market analysis conducted - Outline technical activities associated with business operations - Explain how to prepare a medium / long term sales forecast - Explain creation of an expense budget, long term cash flow statement indicating various fixed and variable costs likely to be encountered - Describe preparation of a cost – benefit analysis and develop a loan repayment plan

UNIT-III:

Demonstrate the structure and functioning of Biomass Depot - Identify key supplier for biomass procurement and supply - Demonstrate the method of sorting, densification and storage of biomass - Explain the mode of stakeholder engagement and identify challenges encountered in daily operations - Describe monitoring of financial performance of the business - Demonstrate resources and inventory management - Identify and demonstrate customer redressal system for solving customer problems

UNIT-IV:

Demonstrate the structure and functioning of Compost yard - Demonstrate method of evaluating material summary reports and identifying technical challenges in composting operations - Describe monitoring of financial performance of the business - Demonstrate method of identifying potential contingencies applicable to the business - Identify methods of

managing key resources i.e. availability of machinery, manpower etc. required during operation - Demonstrate resources and inventory management - Evaluate compost industry best practices for enhance quality - Evaluate the effectiveness of marketing campaigns to identify avenues for enhancing market share and profitability.

UNIT-V:

Demonstrate the structure and functioning of Dry waste Collection Center - Explain various categories of plastic waste, paper waste and other waste - Demonstrate method of evaluating material summary reports and identifying technical challenges in waste collection operations - Describe monitoring of financial performance of the business - Demonstrate method of identifying potential contingencies applicable to the business - Identify methods of managing key resources i.e. availability of machinery, manpower etc. required during treatment / pre-processing of plastic waste, paper waste and other waste - Describe monitoring of non-financial activities of the business which include timely and accurate segregation of plastic waste into various identified categories - Demonstrate disposal / utilization of dry waste in a responsible manner

Text Book

1. Rai, G.D., "Non-Conventional Sources of Energy", Khanna Publishers, Delhi 1995
2. Parker., Colin, & Roberts, Energy from Waste - An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985
3. Shah, Kanti L., Basics of Solid & Hazardous Waste Management Technology, Prentice Hall, 2000

References:

1. Manoj Datta, Waste Disposal in Engineered Landfills, Narosa Publishing House, 1997 Rich, Gerald et.al., Hazardous Waste Management Technology, Podvan Publishers, 1987
2. Bhide AD., Sundaresan BB, Solid Waste Management in Developing Countries, INSDOC, New Delhi,1983.

Course Outcomes

At the end of the course learner will be able to

- ✓ Carry out market analysis
- ✓ Identify key suppliers of waste
- ✓ Manage overall operations of biomass depot
- ✓ Manage overall operations of compost yard
- ✓ Manage overall operations of dry waste collection centre
- ✓ Entrepreneurship skills

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	2	2	3	3	3	3	3	3	3	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPC2102	Dissertation I	8	0	0	20	150	50	200

Course Objective:

CO1 : To design and develop and analyze the renewable energy system / process

Cognitive Level:

K3 : Data / Survey questionnaire preparation
K4 : Data Analysis
K5 : Interpretation of data and report preparation

Student should take up project related to renewable energy and work at GRI or they should obtain a permission to take up industry / institute related project where the external guide will be made available in the organization. However the evaluation is only based on the internal guide. No financial commitment will be given to the external guide. The evaluation of Dissertation is as follows:

CFA:

Seminar I (Identification of Problem & Literature Review) - 25 marks
[Month of August]
Seminar II (Report on the progress of the project) - 25 marks
[Month of October]
Seminar III (Findings and interpretation of results) - 25 marks
[Month of November]

Report Evaluation by External Examiner - 75 marks

Total - 150 marks

ESE:

Viva Voce

[Jointly conducted by internal examiner and external examiner] - 50 marks

Total - 200 marks

Course Outcomes

- ✓ To evolve new device / methodology to evaluate the system performance

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	3	3	3	3	3	3	3	3	3	3	3	3

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPE2101	Village Placement Programme	2	0	0	0	50	0	50

As per Gandhigram Rural Institute – Deemed to be University Norms.

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
Non-Credit Value-Added Course	Inter-Departmental Course	-	2	0	0	50	0	50

Course Code	Course Title	No. of Credits	L	T	P	Max. Marks		
						CFA	ESE	Total
24REPC2201	Dissertation II	**14**	**0**	**0**	**32**	**150**	**50**	**200**

Course Objective:

CO1 : To design and develop and analyze the renewable energy system / process

Cognitive Level:

K3 : Data / Survey questionnaire preparation
K4 : Data Analysis
K5 : Interpretation of data and report preparation

Student should take up project related to renewable energy and work at GRI or they should obtain a permission to take up industry / institute related project where the external guide will be made available in the organization. However the evaluation is only based on the internal guide. No financial commitment will be given to the external guide. The evaluation of Dissertation is as follows:

CFA:

Seminar I (In-depth study of Phase I – Gap to be addressed) - 25 marks
[Month of December]
Seminar II (Report on the progress of the project) - 25 marks
[Month of February]
Seminar III (Findings and interpretation of results) - 25 marks
[Month of April]

Report Evaluation by External Examiner - 75 marks

Total - 150 marks

ESE:

Viva Voce

[Jointly conducted by internal examiner and external examiner] - 50 marks

Total - 200 marks

Course Outcomes

- ✓ To evolve new device / methodology to evaluate the system performance

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
1	3	3	3	3	3	3	3	3	3	3	3	3	3	3