PERIYAR UNIVERSITY, SALEM – 636 011

DEPARTMENT OF ENERGY STUDIES

M.Sc., ENERGY STUDIES

Courses:

Semester - I		Credits
PGESC01	Historical Perspectives of Energy and Environment	4
PGESC02	Applied Mathematics for Energy	4
PGESC03	Renewable Energy Sources	4
PGESC04	Non-Renewable Energy Sources	4
PGESC05	Energy Audit and Management	4
PGESC06	Energy Lab -I	4
Semester - II		
PGESC07	Solar Photovoltaic - I	4
PGESC08	Solar Photovoltaic - II	4
PGESC09	Solar Thermal Energy	4
PGESC10	Wind Energy	4
PGESC11	Grid Integration of Energy Sources	4
PGESC12	Energy Lab –II	4
Internship with Industry (one month)		
Semester – III Electives (Compulsory)		
PGESE01	Advanced Course on Solar Photovoltaic - I	4
PGESE02	Advanced Course on Solar Photovoltaic - II	4
PGESE03	Advanced Course on Solar Thermal Energy	4
PGESE04	Advanced Course on Wind Energy	4
PGESE05	Energy Storage Devices	4
PGESC13	Energy Lab - III	4
Semester – IV		
PGESC14	Project Work	18

PGESC01: Historical Perspectives of Energy and Environment

Introduction to Energy codes and policies: Energy Conservation act, Electricity Act, Solar policy, Hydro policy, Biomass policy. International scenario: world energy outlook, international protocols for energy and environment, governing and nodal national/international agencies and their role. Financial tools: incentives and subsidies, calculation of required subsidy for penetration, concept of shadow price. Concept of micro-financing for RE, funding agencies for RE projects in India, application development for RE funding. Tariff policies, use of Demand Side Management as a policy tool

PGESC02: Applied Mathematics for Energy

Introduction to Numerical Methods: Solution of algebraic and transcendental equations; Solution of simultaneous algebraic equations; Empirical laws and curve-fitting; Regression method for forecasting; Interpolation. Finite Difference Method: Methods: Forward difference, backward difference, central difference; the Δ, $\ddot{\nabla}$, δ, E, and μ operators and their interrelations. Numerical Differentiation and Integration: Differentiation using forward, backward and central difference formulae. Integration using trapezoidal, Simpson's one-third and Simpson's three-eighth rule. Numerical Solution of Differential Equation: Methods: Taylor's series, Euler, Modified Euler, Runge-Kutta and Predictor-corrector method; Numerical solution of Partial Differential Equation: Solution of Laplace's equation, Poisson's equation; Solution of one-dimensional heat equation using Schmidt and Crank-Nicholson method; Solution of two-dimensional heat equation; Solution of wave equation. Optimization Techniques: Introduction; Linear programming methods: Simplex method, artificial variables and dual phase method. Computational Techniques: Computer programming using C; Use of computational software packages like MATLAB, Mathematica etc.

PGESC03: Renewable Energy Sources

Statistics on Conventional Energy Sources and Supply in Developing Countries: Definition, Concepts of NCES, Limitations of RES, Criteria for assessing the potential of NCES, Classification of NCES, Solar, Wind, Geothermal, Biomass, Ocean energy sources, Comparison of these energy sources. Solar Energy: Definition, Energy available from Sun, Solar radiation data, solar energy conversion into heat, Flat plate

and Concentrating collectors, Principle of natural and forced convection, Solar Engines: Sterling, Brayton engines, Photovoltaics: p-n junctions. Solar cells, PV systems, Standalone, Grid connected solar power satellite, Calculation of energy through photovoltaic power generation.

Wind Energy: Energy available from wind, General formula, Lift and drag. Basis of Wind energy conversion, Effect of density, Frequency variances, Angle of attack, Wind speed, Windmill rotors, Horizontal axis and Vertical axis rotors, Determination of torque coefficient, Induction type generators, Working principle of wind power plant.

Nature of Geothermal Sources: Definition and classification of resources, Utilization for electricity generation and direct heating, Wellhead power generating units. Basic features: Atmospheric exhaust and condensing, Exhaust types of conventional steam turbines. Pyrolysis of Biomass to produce solid, liquid and gaseous fuels. Biomass gasification, Constructional details of gasifier.

Wave, Tidal and OTEC energy, Difference between tidal and wave power generation. Principles of tidal and wave power generation, OTEC power plants, Operation of small open-cycle experimental facility.

PGESC04: Non-Renewable Energy Sources

Introduction to Non Renewable energy sources: Oil and Natural Gas (Fossil Fuels): Introduction, Crude Oil Reserves, Natural Gas Reserves, Recovering Oil and Gas, Impact on Environment.

Coal: Introduction, Coal as a Fossil Fuel of the Future, Coal Reserves, Coal Combustion for Power Generation, Environmental Impacts.

Nuclear Energy: Introduction, Energy and Mass, Nuclear Fission, Chain Reaction, Critical Mass, Power from Nuclear Fission Reactors, Thermonuclear Fusion, Difficulties, About Fuel Reserves, Safety and Waste Issues.

Unconventional Oil and Gas Resources: Oil Shale, Tar Sands

Fossil Fuels and Greenhouse Effect: Greenhouse Effect, Energy and Greenhouse Gas Emissions, Weather and Climate, Natural Change of Climate, Global Warming.

PGESC05 Energy audit and Energy management

Energy Management: Concept of energy management, energy demand and supply, economic analysis; Duties and responsibility of energy managers.

Energy Conservation: Basic concepts, Energy conservation in household, transportation, agricultural, service and industrial sectors, Lighting, HVAC systems

Energy Audit: Definition, need, and types of energy audit; Energy management (audit) Approach: Understanding energy costs, bench marking, energy performance, matching energy use to requirement, maximizing system efficiencies, optimizing the input energy Requirements; Fuel & energy substitution; Energy audit instruments; Energy Conservation Act; Duties and responsibilities of energy managers and auditors.

Material and Energy balance: Facility as an energy system; Methods for preparing process flow; material and energy balance diagrams.

Energy Action Planning : Key elements; Force field analysis; Energy policy purpose, perspective, contents, formulation, ratification; Organizing the management: location of energy management, top management support, managerial function, roles and responsibilities of energy manager, accountability; Motivation of employees: Information system-designing barriers, strategies; Marketing and communicating: Training and planning.

Monitoring and Targeting: Defining monitoring & targeting; Elements of monitoring & targeting; Data and information analysis; Techniques: energy consumption, production, cumulative sum of differences (CUSUM); Energy Service Companies; Energy management information systems; SCADA systems.

Electrical Energy Management: Supply side: Methods to minimize supply-demand gap, renovation and modernization of power plants, reactive power management, HVDC, and FACTS. Demand side: conservation in motors, pumps and fan systems; energy efficient motors.

PGESC06: Energy Lab –I

Simulation of renewable energy systems and parametric studies for design using software for RE system design, such as: PVSyst, TRNSYS, HOMER, RETscreen.

Concepts of standalone Solar PV: IV curve response, Impact of temperature, tilt angle, radiation on IV curve. Inverter efficiency, charge controller MPPT tracking(auto and manual),

Experiments on standalone wind energy system: Power curve, cut in speed, coefficient of performance, charge controller efficiency, Battery charging/discharging characteristics, inverter efficiency, THD analysis, power factor.

Experiments on Solar thermal flat plate collector system: Concepts of solar water heating, heat loss coefficient, efficiency, top loss coefficient and the effect of flowrate, wind speed, tilt angle and insolation on system performance.

PGESC07: Solar Photovoltaic – I

Introduction: Solar energy, Greenhouse effect.

Properties of sunlight: Basics of light, black body radiation, solar radiation, Terrestrial solar radiation, solar radiation data.

PN Junction: Basics, Generation, Recombination, Carrier transport, p-n junctions, diode equation of PV, Solar cell operation: Ideal solar cells, solar cell parameters, resistive effects: parasitic, series, shunt other effects: series & shunt resistance, temperature effect, light intensity effect, ideality factor.

Design of silicon cells: Optical properties, reducing recombination, top contact design, solar cell structure

Manufacturing Silicon cells: Silicon wafers and substrates, processing technologies, cell fabrication technologies, solar cell production line.

Modules & Arrays: Module design, interconnection effects, temperature effects, Other considerations including electrical & mechanical insulation, Lifetime of PV modules

Characterization: Measurement of cell efficiency, other IV measurements, IV characterization, optical characterization, lifetime, luminescence and simulation.

Material properties: General properties & optical properties of silicon, Bi_2S_3, CdS, CdSe, CuO, FeS_2, SnS, etc.

PGESC08: Solar Photovoltaic – II

Solar PV systems: Estimating power and energy demand, Site selection, land requirements, choice of modules, economic comparison, balance of systems, off grid systems, grid interface. Preparing DPR, Supporting structures, mounting and installation, battery storage, power condition unit, selection of cables and balance of systems. Planning with software, maintenance and schedule, Monitoring, Data Management, Performance Analysis and Financial Analysis, Solar PV power plants: Array design, inverter types and characteristics, Power conditioning system: working algorithms, performance analysis, Design of stand-alone, hybrid and grid interactive plants, commissioning of solar PV plant

PGESC09: Solar Thermal Energy

Solar Radiation: Basics of Solar Radiation, instruments for measuring solar radiation, solar radiation geometry, empirical equations, solar radiation on tilted surfaces. Liquid Flat plate Collector: Basic elements, performance analysis, transmissivity, absorptivity, heat transfer coefficients and correlations, collector efficiency and heat removal factors, effects of various parameters, types of other liquid flat-plate collectors, transient analysis. Concentrating Collectors: Type of concentrating collectors and their general characteristics, geometry, heat transfer correlations, tracking requirements, performance analysis. Solar thermal power plants: Concentration and temperatures, error in concentration, parabolic geometries, paraboloid geometries(dish), heliostats, layout, central receiver , Component design: Energy balance of components, design process and parameters, thermodynamic basis for receiver design, tube receiver concept. Volumetric receiver, direct absorption receiver, receiver loss calculations, thermal storage for solar power plants. Thermal Energy Storage: Basic methods, Sensible heat storage – liquids- solids-analysis, latent heat storage, thermo-chemical storage, application of thermal storage. Solar field design: array design, control of solar collectors, piping layout, pumping requirements condition monitoring and maintenance systems. Performance analysis of miscellaneous solar applications: Solar Air heaters, solar pond, solar still, solar refrigeration

PGESC10: Wind Energy

Wind Energy Basics: Status, Advantages and disadvantages of wind energy systems, Advantages and disadvantages, Types of wind energy converters, local Effects on wind, site selection: roughness length, wind shear, Wind Speed Variability, Obstacles to wind flow, Working principles of wind energy: Energy content in wind, Energy Conversion at the Blade, Wind variations: Weibull distribution. Components of a wind energy converter: Rotor Blades, Gearboxes, Synchronous or Asynchronous Generators, Towers, Miscellaneous components, Turbine Selection Operation and Control of Wind Energy Converters: grid requirements, Issue of Noise and Its Control, Power Curve and Capacity Factor, Pitch control, Stall Control, Yaw Control

PGESC11: Grid Integration of Energy Sources

Introduction to grid connectivity of RE systems, smart grid and emerging technologies. Operating principles and models of smart gird components, Key technologies for generation, networks, loads and their control capabilities. Decision-making tools, Non-conventional energy source models grid integration, Micro-turbine model and grid integration Energy storage and electric vehicle model, grid integration. Distribution line models, Communication infrastructures for smart grid operation. Advanced metering infrastructure and advanced control methods, Economic dispatch, Demand response and demand management. Distribution feeder analysis, Continuous voltage and frequency control, Contingencies and their management, Unit commitment (selection of generators & loads to operate), Energy constraints: hydro, fuel management and maintenance scheduling, The operational challenges of distributed energy resources, Operation and control issues associated with intermittent generation, Electricity industry operation in a carbon constrained and 'smart grid' future, Impact of smart grid component integration on distribution network operation, Artificial Intelligence based approaches for estimation, scheduling, management and control of next generation smart grid.

PGESC11: Energy Lab II

Concepts of Solar PV Grid-tied system including grid synchronization, power factor correction, anti-islanding effect, effect of transmission line parameters, THD analysis.

Solar PV hardware simulation to understand PV panel performance under different environmental conditions, day & time of the year, geographic location and various PV technologies.

Wind turbine hardware simulation to understand the performance of wind turbine under varying wind speed, blade pitch angle. Power electronic concepts and different inverter controls.

Concepts of solar concentrator thermal system including water heating, heat loss coefficient, efficiency, and the effect of flowrate, wind speed, different heat transfer fluids and insolation on system performance. Sun tracking analysis, concentration ratio and efficiency.

Thermal energy storage concepts to understand charging/ discharging thermal energy cycles, latent heat of fusion, figure of merit and efficiency of various phase changing materials.

Semester – III Electives (Compulsory)

PGESE01 Advanced Solar Photovoltaics- I

Types of systems; advantages and disadvantages , System components & configurations, Backup system types & integration, Grid-interactive system inverters, features, functions, and specifications, Calculations (with & without backup components), Safety issues, procedures, & Indian Grid Code regulations, Site survey and analysis

Solar Photovoltaic design: System design drawings, Feasibility reports, System mechanical and electrical specification calculations, Residential load demands, Supporting documents for utility companies and other regulatory, agencies to approve grid inter-connection, System design requirements and technical specifications as per IEC 62548. Impact of accuracy, reliability of solar radiation data on the plant performance. Matching array & inverter for voltage, current and power. Site assessment & planning for rooftop and MW scale PV power projects. Cost optimization and Detailed Project Report Preparation for MW scale PV projects. Loss estimation & energy yield simulation and Complete design task exercise

PGESE02 Advanced Solar Photovoltaics- II

Grid integration of Solar PV: Inverter Selection, Transformer sizing, MPPT algorithms, Load Sizing, Grid Integration strategies, effect of Transmission line parameters on Integration of solar PV, Islanding effect in Distributed generation systems, Anti-islanding topologies, Fault protection and SCADA in PV operation and control, PV system characteristics and its implications on Grid parameters, approaches to enable high level of PV penetration, Demand side management in solar PV connected network under net metering policies, advanced distribution system and Micro grids, Design Concepts for Integrated Inverters, Controllers, BOS and Energy Management, Advanced systems with energy storage. Balance of reserves

Advanced Power Electronics in Solar PV: DC-DC converter design (buck, boost and buck-boost converters), Load matching for maximum power transfer, DC-AC inverters

design, Power conditioning systems, Type of grid interfaces, VSI and CSI techniques, charge controller design

PGESE03 Wind energy Advanced Course

Site Selection: Review of wind resource assessment, basic laws and concepts of aerodynamics (2-D, 3-D aerodynamics). Description and performance of the horizontal–axis wind machines, description and performance of the vertical–axis wind machines. Site Selection – Wind climatology, terrain features, surface roughness etc. Micro siting of wind turbines, site Identification, wind mast installation. Annual Energy Output estimation, Uncertainties in estimation and Probabilities of Estimation

Rotor Aerodynamics and Blade Design: Principles of wind flow, aero theory: introduction to rotor aerodynamics, blade element momentum model, airfoils theory, design & testing, airfoils rotor specs, wind turbine airfoils. Rotor aero design: basics, design with bladed Advanced aero theory: Rotor design: aeroelastic stability, advanced tip & root design, CoE optimization

Grid Integration and control strategies: Grid Integration issues, Electricity regulatory requirements, Balance of reserves estimation, Advance power electronics in Wind energy operation and control, offshore and onshore wind turbines network design, underground sea cables

PGESE04 Advance solar thermal energy

Solar Heating & Cooling System: Liquid based solar heating system; Natural, forced and gravity flow, mathematical modeling, Vapor 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.

Performances of solar collectors: ASHRAE code; Modeling of solar thermal system components and simulation; Design and sizing of solar heating systems: f – chart method and utilizability methods of solar thermal system evaluation; Development of computer package for solar heating and cooling applications.

Solar Energy for Industrial Process Heat: Industrial process heat: Temperature requirements, consumption pattern; Applications of solar flat plate water heater & air heater for industrial process heat; Designing thermal storage; Transport of energy.

Solar Thermal Energy Systems: Solar still; Solar cooker: Solar pond; Solar passive heating and cooling systems: Trombe wall; Greenhouse technology: Fundamentals, design, modeling and applications.

PGESE05: Energy Storage Devices

Pumped-storage hydroelectricity, Superconducting magnetic energy storage, Battery and Super capacitors: Background and Terminology, Major Battery Chemistries (Advanced Lead Acid, NiMH, Li-ion, others), Battery System Integration Examples, Analysis and Simulation of Batteries Secondary Use, Recycling, Disposal, and Safety of Batteries. Battery Chargers, Protection, and SOC Measurement, Battery Standards and Testing, Application examples (Automotive, Grid-Tied Systems, Etc.) Grid energy storage, Fuel cell and hydrogen technology, Capacitors (e.g. rechargeable electricity storage system), Thermal energy storage, Solar chimney, Compressed fluids (e.g. compressed air), flywheels, Vacuum storage (in rush generation technology), Future Technologies, Super capacitors.

PGESC13 Energy Lab – III

Building energy efficiency lab; eQuest, Design Builder, Energy plus, Dialux, Green Buildings

Semester – IV

PGESC14 Project Work

Books for Study and References

Semester- I

PGESC01: Historical Perspectives of Energy and Environment

1. Masters G. (1991): Introduction to Environmental Engineering and Science, Prentice – Hall International Editions.
2. Ravindranath N.H., Usha Rao K., Natarajan B., Monga P. (2000); Renewable Energy and Environment – A Policy Analysis for India, Tata McGraw Hill
3. Fowler, J.M., (1984); Energy and the environment,2nd Ed., McGraw Hill, New York,

PGESC02: Applied Mathematics for Energy

1. Balagurusamy, E (1999) Numerical Methods, Tata Mc Graw Hill , New Delhi
2. Jain M K., Iyengar S R K., Jain R K (1993) ; Numerical Methods for Scientific and Engineering
   Computation, New Age International (P) Ltd. New Delhi
3. Gupta, A.S., Calculus of Variations with Applications, Prentice Hall of India Pvt. Ltd., New Delhi (1997)
4. Spiegel, M.R., Theory and Problems of Complex Variables and its Application (Schaum's Outline Series), McGraw Hill Book Co., Singapore (1981).
5. Andrews, L.C. and Shivamoggi, B.K., Integral Transforms for Engineers, Prentice Hall of India Pvt. Ltd., New Delhi (2003)

PGESC03: Renewable Energy Sources

1. Kruger P. (2006) Alternative Energy Resources: The Quest for Sustainable E nergy, Wiley publication
2. Rosa Aldo V. (2009) Fundamentals of Renewable Energy Processes, Second Edition, Academic Press
3. Boyle G. (2004) Renewable Energy: Power for a Sustainable Future, Second Edition, Oxford University Press

PGESC04: Non-Renewable Energy Sources

1. Black and Veatch, (1998) ; Power Plant Engineering CBS Pub and Distributors, N Delhi.
2. Nag P K.(2006); Power Plant Engineering, Steam & Nuclear, Tata McGrawHill, N Delhi.
3. Venikov V. A, B V Put Yatin (1984) ; Introduction of Energy Technology, Electric Power Engineering, MIR Publishers, Moscow,

PGESC05 Energy audit and Energy management

1. Smith CB, (1981); Energy Management Principles, Pergamon Press, NewYork,
2. Hamies, (1980); Energy Auditing and Conservation; Methods, Measurements, Management &Case study, Hemisphere, Washington
3. Bureau of Energy Efficiency: Study material for Energy Managers and Auditors Examination: Paper I to IV. 2006
4. Charles M Cotlschalk, Industrial Energy Conservation, John Wiley & Sons, 2002
5. Kennedy, Turner and Capehart, Guide to Energy Management, The Fairmount Press., 1996
6. Kao Chen, Energy Management in Illumination System, CRC Press, 2000
7. Gellingn, Chamberli, Demand Side Management: Concepts and methods, Penwell, 1998

Semester 2

PGESC07: Solar Photovoltaic – I

1. Sukhatme S. P., (2000) ; Solar Energy : Principles of Thermal Collecti on and Storage, Tata McGraw-Hill

2. Duffie J. A. and W.A. Beckman, (2006) ; Solar Engineering of Thermal Processes, John Wiley & Sons

PGESC08: Solar Photovoltaic – II

1. Green M. A (2005) : Third Generation Photovoltics: Advanced Solar Energy, Springer
2. Tiwari, G.N (2002); Solar Energy, Fundamentals design, modeling and Applications, Narosa, New Delhi
3. Goswami, D. Yogi, Frank Kreith, and Jan F. Kreider (1999) Principles of Solar Engineering, Taylor and Francis, USA.

PGESC09: Solar Thermal Energy

1. Goswami D Y, Kreith Frank and Kreider J F, Taylor & Francis (1999); Princi ples of Solar Engineering, Taylor & Francis, USA
2. Tiwari, G.N (2002); Solar Energy, Fundamentals design, modeling and Apllications, Narosa, New Delhi
3. Duffie J. A. and W. A. Beckman, (2006); Solar Engineering of Thermal Proc esses, Johnn Wiley

PGESC10: Wind Energy

1. Johnson G L, (1985) ; Wind Energy Systems, Prentice Hall Inc, New Jersey,
2. Spera David A., (Editor1994) Wind Turbine Technology: Fundamental Concepts of Wind Turbine
   Engineering,American Society of Mechanical Engineers
3. Paul Gipe , Karen Perez, (1999); Wind Energy Basics: A Guide to Small and Micro Wind Systems, Chelsea Green Publishing Company

PGESC11: Grid Integration of Energy Sources

1. H. Lee Willis and W.G. Scott: Distributed Power Generation: Planning and Evaluation, Marcel Dekker, 2000.
2. J. J. Burke: Power Distribution Engineering, Fundamentals and Applications, Marcel Dekker, 1994.
3. T. Gonen: Electric Power Distribution System Engineering, McGraw-Hill 1986
4. M Mohan: Rural electrification for development: policy analysis and applications. Boulder : Westview Press, 1987
5. G. Saunier: Rural electrification guidebook for Asia and the Pacific, Asian Institute of Technology, 1992
6. Brendan Fox et. al.: Wind Power Integration connection and system operational aspects, IET Power and Energy Series 50 (2007).
7. Marco H. Balderas (ed.): Renewable Energy Grid Integration, (Nova Science Publishers, New York, 2009).
8. Nick Jenkin, Janaka Ekavayake: Wind Energy Generation Modeling and Control (Wiley and Sons).
9. AJ Wood and BF Wollenberg: Power Generation, Operation and Control (John Wiley & Sons, New York, 1996).

PGESE01 Advanced Solar Photovoltaics- I

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. D Y Goswami, Frank Kreith and J F Kreider, Principles of Solar Engineering, Taylor & Francis, 1998
4. Alan L Fahrenbruch and Richard H Bube , Fundamentals of Solar Cells: PV Solar Energy Conversion, Academic Press, New York , 1983
5. H S Rauschenbach, Solar Cell Array Design Handbook, Van Nostrand Reinfold Company, New York, 1980.

PGESE02 Advanced Solar Photovoltaics- II

1. Advanced Solar Photovoltaic Design by John. R Balfour
2. Third Generation Photovoltaics: Advanced Solar Energy Conversion by Martin A
3. Grid Converters for Photovoltaic and Wind Power Systems; Remus Teodorescu, Marco Liserre, Pedro Rodriguez

PGESE03 Wind energy Advanced Course

1. J. F. Manwell, J. G. McGowan, A. L. Rogers, Wind Energy Explained , John Wiley & Sons; 1st edition (2002)
2. Tony Burton, David Sharpe, Nick Jenkins, Ervin Bossanyi, Wind Energy Handbook , John Wiley & Sons; 1st edition (2001)
3. Mukund R. Patel, Wind and Solar Power Systems , CRC Press; (1999)
4. Erich Hau, Wind Turbines: Fundamentals, Technologies, Application and Economics, Springer Verlag; (2000)
5. John F. Walker and Nicholas Jenkins, Wind Energy Technology, John Wiley, 1997
6. David A. Spera, (Editor) Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, American Society of Mechanical Engineers; (1994)

PGESE04 Advance solar thermal energy

1. Sonntag, R.E and Van Wylen, G.J.., "Fundamentals of Thermodynamics", Sixth Edition, 2003.
2. Bacon, D.H., "Engineering Thermodynamics ", Butterworth & Co., London, 1989.
3. Saad, M.A., "Thermodynamics for Engineers ", Prentice-Hall of India Pvt. Ltd., 1989
4. Mayhew, A. and Rogers, B., " Engineering Thermodynamics ", Longman Green & Co. Ltd., London, E.L.B.S. 4th Edition, 1994

PGESE05: Energy Storage Devices

1. Energy Storage Fundamentals by Huggins, Robert A
2. S.P. Sukhatme, Solar Energy: principles of Thermal Collection and Storage, Tata McGraw Hill
3. J. A. Duffie and W. A. Beckman, (2006); Solar Engineering of Thermal Processes Johnn Wiley
4. Green, Martin (2005), 3rd Generation Photovoltaic: Advance Solar Energy, Springer
5. Goswami D Y, Frank Kreith and J F Kreider, Taylor & Francis (199 9) ; Principles of Solar Engineering, Taylor & Francis, USA
6. Garg H.P. and Prakash S (1997) ; Solar Energy: Fundamental and A pplication Tata McGrow-Hill, New Delhi
7. Garg H.P, Prakash J, (1997); Solar Energy : Fundamentals & Applications, Tata McGraw- Hill, New Delhi