MODY UNIVERSITY
LAKSHMANGARH - RAJASTHAN
A Leading Women's University

School of Engineering and Technology (SET)
Lakshmangarh (Sikar), Rajasthan 332 311, India
Ph. No.: (1573) 225001-12 • Fax: (01573) 225042
email: dean.set@modyuniversity.ac.in • www.modyuniversity.ac.in

Date: 12.06.2019

Department of Electrical Engineering

Minutes of meeting of the **Board of Studies (B.O.S) in Electrical Engineering Department, SET,** Mody University of Science and Technology held on 12.06.2019 at 10.45 AM in the conference room of AB Building.

Members:

1. Dr. V. K. Jain (Chairman)
2. Dr. Dheerendra Singh, BITS, Pilani (Academic Expert, External Member-BOS)
3. Mr. Bharat Maria, PGCOIL, Sikar (Industry Expert, External Member-BOS)
4. Dr. Sudhir Y Kumar (Member)
5. Dr. Thoudam Paraskumar Singh (Member Secretary)
6. Dr. Sunita Kumari (Member)

The following points were discussed and approved:

1. The members of BOS noted and approve the course structure and course curriculum of **B.Tech. program in Electrical Engineering (2019-2020 Onwards)** of the 4-year program in the Department of Electrical Engineering as per the guidelines of AICTE, ABET/IET/Mody University Model.
2. The members of BOS noted and approve the course structure and course curriculum of **M.Tech. program in Renewable Energy (2019-2020 Onwards)** of the 2-year program in the Department of Electrical Engineering as per the guidelines of AICTE, ABET/IET/Mody University Model.
3. The BOS directed to place the approval before the next UGPC/PGRPC.

Meeting ended with the vote of thanks to the chair.

Dr. Thoudam Paraskumar Singh	Dr. Sudhir Y Kumar	Dr. V. K. Jain
(Member Secretary-BOS)	(Head, EE, SET)	(Chairman-BOS)

MODY UNIVERSITY
LAKSHMANGARH - RAJASTHAN
A Leading Women's University

School of Engineering and Technology (SET)
Lakshmangarh (Sikar), Rajasthan 332 311, India
Ph. No.: (1573) 225001-12 • Fax: (01573) 225042
email: dean.set@modyuniversity.ac.in • www.modyuniversity.ac.in

Date: 12.06.2019

Department of Electrical Engineering

Attendance Sheet

A meeting of board of studies (B.O.S) in Electrical Engineering Department, SET held on 12.06.2019 at 10.45 AM in the conference room of AB Building to discuss and finalize the following agenda items.

1. To finalize and approve the course structure and curriculum of **B. Tech. program in Electrical Engineering (2019-2020 Onwards)** of the 4-year program in the Department of Electrical Engineering as per the guidelines of AICTE, ABET/IET/Mody University Model.
2. To finalize and approve the course structure and curriculum of **M. Tech. program in Renewable Energy (2019-2020 Onwards)** of the 2-year program in the Department of Electrical Engineering as per the guidelines of AICTE, ABET/IET/Mody University Model.
3. Any other matter with the permission of the Chair.

Members:

1. Dr. V. K. Jain (Chairman)
2. Dr. Dheerendra Singh, BITS, Pilani (Academic Expert, External Member-BOS)
3. Mr. Bharat Maria, PGCOIL, Sikar (Industry Expert, External Member-BOS)
4. Dr. Sudhir Y Kumar (Member)
5. Dr. Thoudam Paraskumar Singh (Member Secretary)
6. Dr. Sunita Kumari (Member)

MODY UNIVERSITY
OF SCIENCE AND TECHNOLOGY
LAKSHMANGARH • RAJASTHAN
A Leading Women's University

M. Tech. Renewable Energy

Proposed Syllabi for (2019-2021 Batch Onwards)

Based on New Academic Curriculum

Highlights

AICTE New Model Compatible

Total Credits: 160

University Electives

University Core

Industry Electives

Compiled By:
Syllabus Review Committee

- Dr. V.K. Jain, Chairman – BoS (EE)
- Dr. Sudhir Y Kumar, HoD / EE
- Dr. Th. Paraskumar Singh, Asst. Prof./EE (Member Secretary)
- Dr. Sunita Kumari, Asst. Prof. / EE
- Dr. Shubhashish Bhakta, Asst. Prof. / EE

To be Presented in 37th PGRPC for Approval

Contents

M. Tech. Renewable Energy
Two Year Program
Academic Curriculum (2019-2020 Onwards)

Curriculum Components

Component	Credits
1. University Core (1 Course)	2
2. University Elective	-
3. Basic Science (1 Course)	4
4. Engineering Science (2 Courses)	8
5. Program Core (8 Courses)	26
6. Program Elective (2 Courses)	8
7. Project / Summer Internship Project (4 Courses)	32
8. Proficiency (Non Credit / Non Graded)*	-
Total	**80**

Credit Distribution across all Components								
Semester	**UC**	**UE**	**BS**	**ES**	**PC**	**PE**	**PR**	**Total**
First	**0**	**0**	**4**	**4**	**12**	**4**	**0**	**24**
Second	**2**	**0**	**0**	**4**	**14**	**4**	**0**	**24**
Third	**0**	**0**	**0**	**0**	**0**	**0**	**16**	**16**
Fourth	**0**	**0**	**0**	**0**	**0**	**0**	**16**	**16**
Total	**2**	**0**	**4**	**8**	**26**	**8**	**32**	**80**

Acronym	
UC	**University Core**
UE	**University Elective**
BS	**Basic Science**
ES	**Engineering Science**
PC	**Program Core**
PE	**Program Elective**
PR	**Project/Summer Internship**

M. Tech. Renewable Energy
Two Year Program
Academic Curriculum (2019-2020 Onwards)

First Year

	Course Code	Course Title	Contact Hours per Week			Credits	ETE Duration	Weightage (%)		
			L	T	P		Hours	*CW	MTE **	ETE
Autumn Semester	EE 19.501	Energy Resources	3	1	0	4	3	10	40	50
	ME 19.501	Heat Transfer and Fluid Mechanics	3	1	0	4	3	10	40	50
	EE 19.503	Solar Energy Engineering	3	1	0	4	3	10	40	50
	MA 19.509	Advanced Mathematics	3	1	0	4	3	10	40	50
		Elective-I	4	0	0	4	3	10	40	50
	EE 19.531	Basic RE Simulation Laboratory-I	0	0	4	2	3	20	40	40
	EE 19.533	Basic RE Simulation Laboratory-II	0	0	4	2	3	20	40	40
	Sub Total		**16**	**4**	**4**	**24**				
	Proficiency (Non Credit, Non Grade)									

	Course Code	Course Title	Contact Hours per Week			Credits	ETE Duration	Weightage (%)		
			L	T	P		Hours	*CW	MTE **	ETE
Spring Semester		Social and Professional Ethics	2	0	0	2	3	10	40	50
	EE 19.502	Energy Management and Auditing	3	1	0	4	3	10	40	50
	EE 19.504	Wind Energy Technology	3	1	0	4	3	10	40	50
	EE 19.506	Solar Photovoltaic Engineering	3	1	0	4	3	10	40	50
	ME 19.502	Thermal Engineering	3	1	0	4	3	10	40	50
		Elective-II	4	0	0	4	3	10	40	50
	EE 19.532	Advanced RE Simulation Laboratory	0	0	4	2	3	20	40	40
	Sub Total		**16**	**4**	**4**	**24**				

Total Credits = 24 + 24 + 16 + 16 = 80

***Theory: Assignments and regularity** will be evaluated out of 10(ten) marks in a semester.
****Theory:** One mid-term examinations of 40 (forty) marks.

M. Tech. Renewable Energy
Two Year Program
Academic Curriculum (2019-2020 Onwards)

Second Year

	Course Code	Course Title	Contact Hours per Week			Credits	ETE Duration	Weightage (%)		
			L	T	P		Hours	*CW	MTE **	ETE
Autumn Semester	EE 19.601	Seminar	-	-	-	4	-	100		
	EE 19.631	Project	-	-	-	4	-	100		
	EE 19.633	Dissertation Preliminary	-	-	-	8	-	100		
	Sub Total		**-**	**-**	**-**	**16**	-			

	Course Code	Course Title	Contact Hours per Week			Credits	ETE Duration	Weightage (%)		
			L	T	P		Hours	*CW	MTE **	ETE
Spring Semester	EE 19.634	Dissertation Final	-	-	-	16	-	100		
	Sub Total		**-**	**-**	**-**	**16**	-			

Total Credits = 24 + 24 + 16 + 16 = 80

***Theory: Assignments and regularity** will be evaluated out of 10(ten) marks in a semester.
****Theory:** One mid-term examinations of 40 (forty) marks.

List of Electives

Autumn Semester (Elective-I)

1	EE 19.505	Advanced Energy Storage System
2	EE 19.507	Biomass and Small Hydel Plants
3	ME 19.511	Energy Forecasting Modeling and Project Management
4	EE 19.509	Power system and Smart Grid

Spring Semester (Elective-II)

1	EE 19.508	Environmental Impact of Energy System
2	EE 19.510	Power System for Renewable Energy Source
3	ME 19.512	Solar Refrigeration and Air Conditioning
4	EE 19.512	Power Electronics for Renewable Energy Source

EE 19.501 **Energy Resources** **Total Lectures: 40**

3-1-0-4

Objective:
- To provide an exposure on various concepts of Non-renewable and renewable energy and also its domestics and industrial applications
- To understand the environmental and economic aspects of renewable energy sources

Prerequisite: Power Plant Engineering

1. **Commercial Energy:** Coal, Oil, Natural Gas, Nuclear power and Hydro – their utilization pattern, future projections of energy consumption, environmental impact of fossil fuels, Energy scenario in India – Growth of energy sector and its planning in India. [8]
2. **Bio Energy:** Biomass resources and their classification, Biomass conversion processes, Thermo chemical conversion - direct combustion, biomass gasification, pyrolysis and liquefaction, biochemical conversion, anaerobic digestion, types of biogas Plants, applications, alcohol production from biomass, bio diesel production, Urban waste to energy conversion, Biomass energy program in India. [8]
3. **Solar Energy:** Solar radiation at the earth's surface, measurements and estimation of average solar radiation, solar thermal flat plate collectors, concentrating collectors, solar thermal applications, solar electric power plant - principle of photovoltaic conversion of solar energy, types of solar cells, Photovoltaic applications: battery charger, domestic lighting, street lighting, water pumping etc - solar PV power plant, Net metering concept. [8]
4. **Wind Energy:** Nature of the wind, power in the wind, factors influencing wind, wind data and energy estimation, wind speed monitoring, wind resource assessment, Betz limit, site selection, wind energy conversion devices, classification, applications, safety and environmental aspects, wind energy potential and installation in India -Repowering concept. [8]
5. **Other Types of Energy:** Ocean energy resources, principle of ocean thermal energy conversion (OTEC), ocean thermal power plants, ocean wave energy conversion, tidal energy conversion, small hydro, geothermal energy, geothermal power plants, hydrogen production and storage, Fuel cell: principle of working, various types, construction and applications. [8]

Course Outcome: Upon successful completion of this course, students should be able to:
- Understanding of commercial energy and renewable energy sources
- Knowledge in working principle of various energy systems
- Capability to do basic design of renewable energy systems

Text Books:
1. Peter Gevorkian, Sustainable Energy Systems Engineering, McGraw Hill, 4th edition2006.
2. Godfrey Boyle, Renewable Energy: Power for a Sustainable Future, Oxford University Press, 3rd edition, 2012.

Reference Books:
1. Veziroglu, T.N., Alternative Energy Sources, Vol 5 and 6, McGraw-Hill, 6th Edition 2011.
2. Twidell, J.W. and Weir, A., Renewable Energy Sources, EFN Spon Ltd, 2nd Edition, 2006.

ME 19.501 **Heat Transfer and Fluid Mechanics** **Total Lectures: 40**

3-1-0-4

Objective: To provide the exposure in analysis of heat transfer rate and physical behavior of fluid.

Prerequisite: Physics & Mathematics

1. **Fundamental Equations of Conduction:** General different equation of heat conduction in Cartesian, cylindrical and spherical coordinate system, one dimensional steady state heat conduction, systems without internal heat generation, systems with variable thermal conductivity, composite systems, critical radius of insulation. [9]

2. **Fundamental of Convective Heat Transfer:** Introduction, convective heat transfer coefficient, basic equation, boundary layer concept, laminar heat transfer over flat plate, fully developed heat transfer through smooth pipes, the case of contact heat flux and constant wall temperature boundary condition, dimensional analysis, Correlation of heat transfer in turbulent flow, use of hydraulic diameter, free convection heat transfer phenomena, heat exchangers, Log mean temperature difference, Effectiveness and NTU. [9]

3. **Thermal Radiation:** Basic concept, Theory of thermal radiation, electromagnetic spectrum, Wien's displacement law, Stefan-Boltzmann equation, Concept of black gray bodies without participating media, radiation shields, View factors, Equivalent emissivity of grooved surfaces electrical network analogies. [9]

4. **Introduction:** Physical properties of fluids, concept of shear stress, Newtonian and Non - Newtonian fluids. [4]

5. **Kinematics & Dynamics of Fluid Flow:** Types of fluid flow, stream lines, streak lines, path lines, stream tubes, stream function and velocity potential, flow nets, Euler's equation of motion along a streamline and its integration, Bernoulli's equation and momentum equation. Boundary Layer Analysis, Boundary Layer Thickness, Boundary Layer over a flat plate. [9]

Course Outcome: Upon successful completion of this course, students should be able to:

- Determine heat transfer rate through plane, cylindrical and spherical surfaces, understand non dimensional number and their physical significance.
- Understand the uses of heat exchanger, physical behavior of fluids and determine the head loss due to friction.

Text Books:

1. Nag P. K, "Heat & mass transfer", McGraw Hill, 3rd Edition, 2011.
2. Holman J. P, "Heat Transfer (in SI units)", McGraw Hill, 9thEdition, 2008.

Reference Books:

1. Som S and Biswas G, "Introduction to Fluid Mechanics and Fluid Machines", McGraw-Hill, 2nd edition, 2007.
2. Cengal Y and Cimbala J, "Fluid Mechanics", McGraw Hill, 6th edition, 2010.

EE 19.503 **Solar Energy Engineering** **Total Lectures: 40**
3-1-0-4

Objective:
- To develop the ability to understand / analyze the various solar energy design principles.
- To study the various applications of solar energy and storage systems.

Prerequisite: Renewable Energy System.

1. **Introduction:** Source of radiation, solar constant, solar charts, Measurement of diffuse, global and direct solar radiation: pyrheliometer, pyranometer, pyregeometer, net pyradiometer-sunshine recorder. [5]
2. **Solar Non-Concentrating Collectors**: Design considerations, Classification- air, liquid heating collectors, Derivation of efficiency and testing of flat plate collectors, Analysis of concentric tube collector, Solar green house. [6]
3. **Solar System Design**: Classification, Concentrator mounting, Focusing solar concentrators, Heliostats. Solar powered absorption A/C system, water pump, chimney, drier, dehumidifier, still, cooker. [12]
   Photo-Voltaic Cell: Characteristics-cell arrays-power electric circuits for output of solar panels, choppers, inverters, batteries-charge regulators, Construction concepts.
4. **Energy Storage**: Sensible, latent heat and thermo-chemical storage-pebble bed etc. materials for phase change-Glauber's salt-organic compounds. [10]
5. **Solar Energy Applications**: Introduction and principle of operation of solar cooker, solar air heater, solar water heater, solar distillation, solar pond, solar thermal power generation – Greenhouse - Solar PV system. [7]

Course Outcome: Upon successful completion of this course, students should be able to
- Analyze and design the solar energy system with energy storage devices and perform the selection based on techno-economic view point.

Text Books:
1. D. Yogi Goswami, Frank Kreith, Jan. F. Kreider, "Principles of Solar Engineering", 2nd Edition, Taylor & Francis, 2000, Indian reprint, 2003.
2. Edward E. Anderson, "Fundamentals for solar energy conversion", Addison Wesley Publ. Co., 2nd Edition 2000.

Reference :Books
1. G. N. Tiwari and M. K. Ghosal, "Fundamentals of Renewable energy Sources", Narosa Publishing House, New Delhi, 4th Edition,2007.
2. Energy Studies, Second Edition, by W. Shepherd and D. W. Shepherd, Imperial College Press, London,3rd Edition, 2004.

MA 19.509 **Advanced Mathematics** **Total Lectures: 40**

3-1-0-4

Objective: To acquire fundamental knowledge computational numerical techniques and fundamentals of statistics and probability and apply in inter-disciplinary engineering disciplines.

Prerequisite: Engineering Mathematics

1. **Computer based numerical methods:** Methods for numerical solution of algebraic and transcendental equations: Direct methods e.g. Bisection method, Regula-Falsi method; Iterative method e.g. Newton-Raphson method. Methods for the solution of simultaneous linear equations: Direct methods e.g. Gauss elimination method; Iterative method e.g. Gauss-Seidel method, Jacobi method. [8]
2. **Finite difference** table for equal and unequal intervals in the independent variable values. Newton's forward and backward interpolation formula; Newton's interpolation formula for divided differences. Numerical differentiation. [8]
3. **Numerical Integration methods:** Simpson's rules, Trapezoidal rule and Romberg's method. Numerical solution of ordinary differential equations: Euler method, Modified Euler method and Runge-Kutta methods. Numerical solution of elliptic and parabolic differential equations using finite difference approach. [8]
4. **Statistics and Probability:**Concept of random variable, total and conditional probability, Bayes' theorem, probability distributions and probability density functions, moments and moment generating functions. Some theoretical probability distributions such as binomial, Poisson, normal, uniform, exponential, rectangular, χ^2, t, F. [8]
5. **Sampling theory:** sampling distributions and sampling techniques. Estimation theory, Point and Interval estimation of mean and variance of data. Testing of hypotheses. Simple and Composite hypothesis. Correlation and Regression. Multiple and Partial correlation and regression. Concepts of stochastic processes with special reference to Monte Carlo methods. [8]

Course Outcome: After completion of the course, students would be able to apply the knowledge of computational numerical techniques with statistics and probability theory in inter-disciplinary engineering and solve curriculum problems.

Text Books:

1. Shastri S.S., *Introductory Method of Numerical Analysis, Prentice-Hall of India*, 3rd Ed., 2002.
2. Trivedi K.S., *Probability and Statistics with Reliability Queuing and Computer Science Application*, Prentice-Hall of India, 2002.

Reference: Books

1. Papoulis, Probability, *Random Variables and Stochastic Processes*, TMH, 2018.
2. Gupta & Kapoor, *Fundamental of Mathematical Statistics, SCS Publisher*, 2002.
3. Dass and Verma, *Higher Engineering Mathematics*, S.Chand, 2019.

EE 19.531 **Basic RE Simulation Laboratory-I** **Total Hours: 26**

0-0-4-2

Objective: To provide the basic knowledge and understanding on various aspects of renewable energy system using MATLAB/Simulink Software.

Pre-requisite: Elements of Electrical Engineering

List of Experiments

1. To study in details about the MATLAB software and its applications.
2. To determine the intensity of solar radiation.
3. To study the performance evaluation of a solar PV panel.
4. Setting up of the Photovoltaic panel with the help of the given settings to get the maximum exposure of the sunlight.
5. Connection of Photovoltaic cells in series and measuring their V/I Characteristics.
6. Connection of Photovoltaic cells in parallel and measuring their V/I Characteristics.
7. To model single phase and three phase inverter.
8. Connecting a solar panel with inverter and measuring the output using meter.
9. Connecting a battery to the inverter and measuring the output using a meter.
10. To model a phase controlled rectifier and control speed of DC motor.

Course Outcome: Upon successful completion of this course, students should learn the basic knowledge and understanding on various aspects of renewable energy system using MATLAB/Simulink Software.

EE 19.533 **Basic RE Simulation Laboratory-II** **Total Hours: 26**

0-0-4-2

Objective: To provide the basic knowledge and understanding on various aspects of renewable energy system using ETAP software.

Pre-requisite: Power System I, Power System II

List of Experiments

1. To study in details about the ETAP software and its applications.
2. To implement the single line diagram of a given power system.
3. To Measure sending and receiving end line parameters of short/medium/long transmission line and Modeling of transmission line model.
4. Short-circuit analysis of standard test systems.
5. Transient stability analysis of standard test systems.
6. Fast De-coupled for both PQ and PV Buses.
7. Load forecasting.
8. Transformer Tests.
9. Perform the load flow analysis of power system using Newton-Raphson method.
10. Perform the load flow analysis of power system using Gauss-Seidel method.

Course Outcome: Upon successful completion of this course, students should learn the basic knowledge and understanding on various aspects of renewable energy system using ETAP software.

UC 19.101 **Social and Professional Ethics** **Total Lectures: 26**
2-0-0-2

Objective: To create an awareness on professional ethics and human values, To instill moral and social values and loyalty and to appreciate the rights of others.

Pre-requisite:

1. **Basic Human Values:** Morals, Values and Ethics – Truth, Rights Conduct (Righteousness), Love, non-violence and peace, Humility and character. Core areas of ethics: Social ethics, Personal ethics Integrity and Trustworthiness, Honesty, Loyalty, Courage, Prudence, Confidence, Confidentiality. **[5]**
2. **Theories of Ethics:** Kohlberg and Gilligan's analysis of moral development, - Deontology, Utilitarianism, Virtue Theory Rights Theory, Casuist Theory of Consequentialism – Robert Nozick's Theory of Entitlement and Property Rights. **[4]**
3. **Professional Ethics:** Introduction, meaning of work ethics, professional ethics for Journalists, Physicians, Lawyers, Engineers and Accountants. Intellectual property Rights, scope of ethics, code of conduct, business values and inner consciousness, Ethics at the workplace cybercrime, plagiarism, misconduct, fraudulent use of institutional resources, etc. **[7]**
4. **Corporate Social Responsibility:** Evolution of Corporate Social Responsibility (CSR) in India, CSR models, CSR to different stakeholders, Corporate Social Responsibility Initiatives of Major Companies of India, Promoting value based governance in organization. Whistle blower policy. **[6]**
5. **Ethics and Environment:** Introduction to environmental Issues- Industry and Environmental Pollution, Ethics of Controlling environmental pollution – Impact of environmental pollution on human health – Rights, Duties and care in environmental protection - Sustainable development. **[4]**

Outcome: The students will understand the basic perception of profession, professional ethics, various moral issues and uses of ethical theories.

Text Books:

1. B.N Ghosh "Business Ethics and Corporate Governance", McGraw Hill Education, Chennai, 2016
2. John R Boatright, "Ethics And The Conduct Of Business", Pearson Education, New Delhi, 2013.

Reference Books:

1. Raju Ramachandran, "Professional Ethics: Changing Profession and Changing Ethics", LexisNexis, Butterworths, 2nd Edition 2014.
2. Andrew Crane and Dirk Matten, "Business Ethics", Oxford University Press, 2nd Edition, 2015.
3. S.K Mandal "Ethics in Business and Corporate Governance" McGraw Hill Education, New Delhi, 2013.
4. R. Subramanian "Professional Ethics", Oxford University Press, 2015.

EE 19.502 **Energy Management and Auditing** **Total Lectures: 40**
3-1-0-4

Objective:
- To provide a broad knowledge on current energy scenario and audit for various applications.
- To acquire the in-depth knowledge of the Energy management systems.

Prerequisite: Renewable Energy System

1. **Energy Scenario**: Role of Energy Managers in Industries , Energy monitoring, auditing & targeting , Economics of various Energy Conservation schemes, Total Energy Systems [8]
2. **Energy Audit**: Various Energy Conservation Measures in Steam, Losses in Boiler. Energy Conservation in Steam Systems, Case studies. [8]
3. **Basics of Energy Conservation:** Energy conservation in Centrifugal pumps, Fans & Blowers, Air compressor, energy consumption & energy saving potentials, Design consideration. [8]
4. **Refrigeration & Air conditioning:** Heat load estimation, Energy conservation in cooling towers & sprays ponds; Case studies Electrical Energy, Energy Efficiency in Lighting, Case studies. [8]
5. **Energy Management:** Organizational background desired for energy management motivation, detailed process of M&T-Thermostats, Boiler controls, proportional, differential and integral control, optimizers; compensators. [8]

Course Outcome: Upon successful completion of this course, students should be able to
- Perform energy audit on the systems and know in depth the energy management systems.

Text Books:
1. Eastop T.D & Croft D.R, Energy Efficiency for Engineers and Technologists, Logman Scientific & Technical, ISBN-0-582-03184, 1990.
2. Reay D.A, Industrial Energy Conservation, 1st Edition, Pergamon Press, 6th edition, 2008.

Reference Books:
1. L. C Witte, Philip S. Schmidt, D. R. Brown, Industrial Energy Management & Utilization, Hemisphere Publisher Corp., 1st edition, 1988.
2. Power System Engineering 2nd Ed. D P Kothari, I J Nagrath, McGraw-Hill, 4th edition, 2008.

EE 19.504 **Wind Energy Technology** **Total Lectures: 40**

3-1-0-4

Objective: To provide the current status, importance, future trends and potential for Wind energy technologies as a complement to, or replacement for, conventional technologies.

Prerequisite: Renewable Energy System

1. **Wind Resource:** Wind characteristics: Meteorology of wind – wind speed distribution across the world – spatial and temporal factors – Eolian features - Biological indicators. Wind measurement: Anemometers – balloon trackers. Wind energy conversion systems (WECS) - classifications. [8]

2. **Wind Energy Conversion:** Aerodynamic design principles; Aerodynamic theories; Axial momentum, blade element and Strip theory; Maximum power coefficient; Prandlt's tip loss correction; Rotor design and characteristics; Power, torque and speed characteristics – Wind turbine performance measurement – Loading analysis. [8]

3. **Wind Turbines Types:** Vertical Axis Type, Horizontal Axis, Constant Speed Constant Frequency, Variable speed Variable Frequency, Up Wind, Down Wind, Stall Control , Pitch Control, Gear Coupled Generator type, Direct Generator Drive /PMG/Rotor Excited Sync Generator. [8]

4. **Wind Energy Application:** Wind pumps: Performance analysis, design concept and testing; Principle of Wind Energy Generators; Stand alone, grid connected and hybrid applications of WECS; Economics of wind energy utilization; Wind energy in India; Case studies. [8]

5. **Cost Economics**: Wind resource assessment and R & D costs, Fixed and variable costs, Value of wind energy, Life cycle costing and cash flow of wind power projects, Wind project owners / developers, Wind energy market. [8]

Course Outcome: Upon successful completion of this course, students should be able to

- Understand the atmospheric processes that produce wind energy.
- Explain the fundamental principle of wind turbine operation.
- Analyze the economics of wind energy.
- Explain recent commercial developments in wind energy and its future potential.

Text Books:

1. S. Rao & B. B. Parulekar, Energy Technology, Khanna publishers, 4th Edition, 2005.
2. T. Burton, D. Sharpe, N. Jenkins and E. Bossanyi, Wind energy Handbook, John Wiley & Sons, 6th Edition, 2011.

Reference Books:

1. Mukund. R. Patel, Wind and Solar Power Systems, Taylor & Francis, 2nd Edition 2001.
2. L .L. Freris, Wind Energy Conversion Systems, Prentice Hall, 4th Edition, 2010.

EE 19.506 **Solar Photovoltaic Engineering** **Total Lectures: 40**

3-1-0-4

Objective:
- To attain a broad comprehension of solar photovoltaic systems used for various applications.
- To know in depth the types and design of various PV-interconnected systems.

Prerequisite: Renewable Energy System

1. **Photovoltaic Basics:** Structure and working of Solar Cells - Types, Electrical properties and Behavior of Solar Cells – Cell properties and design - PV Cell Interconnection and Module Fabrication - PV Modules and arrays -Basics of Load Estimation. [8]
2. **Stand Alone PV Systems:** Schematics, Components, Batteries, Charge Conditioners - Balance of system components for DC and/or AC Applications - Typical applications for lighting, water pumping etc. [8]
3. **Grid Connected PV Systems:** Site selection and land requirements - Techno-economic analysis of solar PV power plants - Environmental considerations. Schematics, Components, Charge Conditioners, Interface Components - Balance of system Components - PV System in Buildings. [8]
4. **Design of PV Systems:** Radiation and load data - Design of System Components for different PV Applications - Sizing and Reliability - Simple Case Studies. [8]
5. **Solar Economics:** Application of economic methods to analyze the feasibility of solar systems to decide project / policy alternatives - Net energy analysis - and cost requirements for active and passive heating and cooling - for electric power generation - and for industrial process-heating. [8]

Course Outcome: Upon successful completion of this course students will be able to
- Explain basics of solar photovoltaic systems.
- To know in depth of its types and design of various PV-interconnected systems.

Text Books:
1. CS Solanki, Solar Photovoltaics: Fundamentals, Technologies and Applications, PHI Learning Pvt. Ltd., 2nd Edition 2011.
2. Martin A. Green, Solar Cells: Operating Principles, Technology and System Applications, Prentice- Hall, 4thEdition, 2011.

Reference Books:
1. Nelson J., The Physics of Solar Cells, Imperial College Press, 2nd Edition, 2003.
2. Thomas Markvart, Solar Electricity, John Wiley and Sons, 2nd Edition, 2012.

ME 19.502 **Thermal Engineering** **Total Lectures: 40**

3-1-0-4

Objective:

- To provide analytical methods for the determination of the direction of processes from the first and second laws of thermodynamics.
- To develop the ability of analyzing vapor and gas power cycles
- To provide the students a strong background in the refrigeration cycle

Prerequisite: Physics, Mathematics.

1. **Introduction**: Thermodynamic system - types – properties – Laws of thermodynamics – Concepts of entropy - Second Law of thermodynamics – Clausius inequality – Available energy –irreversibility. [6]

2. **Steam Power Cycles:** Steam power plant – Rankine Cycle – Carnot Cycle – Mean Temperature of Heat addition –Effect of variation of steam condition on thermal efficiency of steam power plant – Reheating of Steam – Regeneration – Feed water heaters – Carnotization of Rankine Cycle – optimum degree of regeneration – optimum degree of regeneration – Deaerator –Efficiencies in a steam power plant - [8]

3. **Steam Turbines:** Introduction; Classification of steam turbine-Impulse turbine-Working principal - Compounding of impulse turbine - Velocity diagram - Calculation of power output and efficiency – Maximum efficiency of a single stage impulse turbine-Impulse reaction turbine - Working principle - Degree of reaction - Parsons turbine -Velocity diagram; Calculation of power output. [9]

4. **Gas Power Cycles**: Carnot cycle - Air standard assumptions - Otto cycle - Diesel cycle – Dual cycle –Stirling cycle – Ericsson cycle – Brayton cycle – Brayton cycle with Intercooling, Reheating and Regeneration. [8]

5. **Air Compressor:** Reciprocating air compressors. Types – Construction - Work of compression without clearance - Effect of clearance – Multi staging. Optimum intermediate pressure for perfect inter cooling - Compressor efficiencies and mean effective pressure. [9]

Course Outcome: Upon successful completion of this course, students should be able to:

- Gain the analytical methods for the determination of the direction of processes from the first and second laws of thermodynamics and to carry out the thermodynamic analysis using equations of potentials, availability, and energy.
- Demonstrate a basic understanding of the nature of the Thermodynamic processes for pure substances and ideal gases.
- Select and analyze a turbine & compressor.

Text Books:

1. Ballaney P. L, "Thermal Engineering", Khanna Publishers, 25th Edition, 2014.
2. Nag P. K, "Basic and Applied thermodynamics", McGraw Hill, 5th Edition, 2013.

Reference Books:

1. Mahesh M Rathore "Thermal Engineering", McGraw Hill, 2nd Edition, 2010.

EE 19.532 **Advanced RE Simulation Laboratory** **Total Hours: 26**
0-0-4-2

Objective:
- To provide the basic knowledge and understanding on various aspects of renewable energy system.

Pre-requisite: Power System

List of Experiments

1. Determining the intensity of solar radiation.
2. Estimation of efficiency of solar photovoltaic panels.
3. Study on charging characteristics of a lead acid battery using solar photo voltaic panel.
4. Model and control a Buck converter and a Boost converter using open loop control system.
5. Model and control a Buck converter and a Boost converter using closed loop control system.
6. Model and control a Buck-Boost converter using open loop control system.
7. Model and control a Buck-Boost converter using closed loop control system.
8. To study on charging characteristics of a lead acid battery using solar photo voltaic panel.
9. To study the performance characteristics of wind energy generator.
10. Noise level study of wind turbine system.
11. Effect of Shadow & tilt angle on solar photo voltaic panel.
12. Illumination from window and skylight, electric lighting integration.
13. Thermal energy audit: Measurement of variables such as air flow, pressure.
14. Measurement and analysis of heat gain and air-conditioning load in a building.

Outcome: Upon successful completion of this course, students should
- Learn the advanced knowledge and understanding on various aspects of renewable energy system.

EE 19.505 **Advanced Energy Storage System** **Total Lectures: 52**
4-0-0-4

Objective:
- To develop the ability to understand / analyze the various types of energy storage.
- To study the various applications of energy storage systems.

Prerequisite: Power Plant Engineering

1. **Introduction:** Necessity of energy storage, types of energy storage, comparison of energy storage technologies, Applications. [7]
2. **Thermal Storage System:** Thermal storage, Types, Modelling of thermal storage units, Simple water and rock bed storage system, pressurized water storage system, Modelling of phase change storage system, Simple units, packed bed storage units, Modelling using porous medium approach, Use of Transys. [9]
3. **Electrical Energy Storage:** Fundamental concept of batteries, measuring of battery performance, charging and discharging of a battery, storage density, energy density, and safety issues. Types of batteries, Lead Acid, Nickel-Cadmium, Zinc Manganese dioxide and modern batteries: zinc-Air, Nickel Hydride, Lithium Battery. [12]
4. **Fuel Cell:** Fuel Cell, History of Fuel cell, Principles of Electrochemical storage, Types, Hydrogen oxygen cells, Hydrogen air cell, Hydrocarbon air cell, alkaline fuel cell, detailed analysis, advantage and drawback of each type. [10]
5. **Alternate Energy Storage Technologies:** Flywheel, Super capacitors, Principles & Methods, Applications, Compressed air Energy storage, Concept of Hybrid Storage, Applications. [14]

Course Outcome: Upon successful completion of this course, students should be able to
- Analyze various types of energy storage devices and perform the selection based on techno-economic view point.

Text Books:
1. Ibrahim Dincer and Mark A. Rosen, Thermal Energy Storage Systems and Applications, John Wiley & Sons, 2nd edition, 2011.
2. Ru-Shiliu, Leizhang, Xueliang Sun, Electrochemical technologies for energy storage and conversion, Volume 1 & 2, Wiley publications,2nd Edition, 2012.

Reference Books
1. James Larminie and Andrew Dicks, Fuel cell systems Explained, Wiley publications, 1st edition, 2003.

EE 19.507 **Biomass and Small Hydel Plants** **Total Lectures: 52**
4-0-0-4

Objective:
- To provide understanding of the processes for converting biomass feedstocks to fuels by various approaches.
- To learn to evaluate technological, economic and business dimensions of energy production from biomass.
- To provide understanding of energy generation from small hydro power plant and hydel power plants management.

Prerequisite: Renewable Energy Sources

1. **Biomass Resources and Biomass Properties:** Biomass: definition, classification, availability, estimation of availability, consumption and surplus biomass, energy plantations. Potential of biomass and assessment. [8]
2. **Energy Conversions Techniques:** Thermo chemical conversion: Direct combustion, incineration, pyrolysis and gasification; Biomass stoves, improved chullahs and some exotic designs, Biological conversion: Biodegradation and biodegradability of substrate; Biochemistry and process parameters of biomethanation; Biogas digester types; Digester design and biogas utilisation; Bioconversion of substrates into alcohol: Methanol & ethanol Production, Chemical conversion: Hydrolysis and hydrogenation; Solvent extraction of hydrocarbons; Bioethanol; Chemicals from biomass. [11]
3. **Bio Diesel:** History, Production methods of Bio-diesel: Transesterification, Fuel quality, standards and properties, Availability of Raw materials for bio-diesel, Applications, Bio-diesel potential in India. [8]
4. **Waste To Energy** Introduction to Energy from waste, classification of waste as fuel, agro based, forest residue, industrial waste, Environmental monitoring system for land fill gases, Environmental impacts; Measures of mitigate environmental effects due to incineration. [7]
5. **Hydro Power:** 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. [9]
6. **Hydel Plant Management:** Speed and voltage regulation; Investment issues load management and tariff collection; Distribution and marketing issues: case studies; Potential of small hydro power in North East India. [9]

Course Outcome: Upon successful completion of this course, students should be able to:
- Understand the challenges and problems associated with the use of various bioenergy sources with regard to future resource and the environment.
- Evaluate the cost-benefit of various biomass energy conversion processes.
- Identify remedies/potential solutions to the supply and environmental issues associated with biomass based energy resources.
- Conceptualize energy generation techniques and understand different small hydro power plant and hydel power plants management.

Text Books:
1. Capareda S, Introduction to biomass energy conversion, CRC Press, 4thEdition, 2014.
2. Harvey A. & Brown A, Micro-Hydro Design Manual: A Guide to Small-Scale Water Power Schemes. Practical Action publication, 2nd Edition, 2003.

Reference : Books
1. Brown RC and Stevens C, Thermo-chemical Processing of Biomass: Conversion into Fuels, Chemicals and Power, Wiley and Sons, 4th Edition, 2011.

ME 19.511 **Energy Forecasting, Modelling and Project Management** **Total Lectures: 52**

4-0-0-4

Objective:
- To develop forecasting models and optimization models for energy planning.
- To equip the students in writing project proposals and making project cost estimation.
- To evaluate the limit cost of energy for various renewable energy systems.

Prerequisite: Operation Research & Management

1. **Energy Scenario:** Role of energy in economic development and social transformation: Energy & GDP, GNP and its dynamics - Energy Sources and Overall Energy demand and Availability - Energy Consumption in various sectors and its changing pattern Status of Nuclear and Renewable Energy: Present Status and future promise. [12]
2. **Forecasting Model:** Forecasting Techniques - Regression Analysis - Double Moving Average - Double Experimental Smoothing - Triple Exponential Smoothing – ARIMA model - Validation techniques – Qualitative forecasting – Delphi technique - Concept of Neural Net Works. [10]
3. **Optimization Model:** Principles of Optimization - Formulation of Objective Function - Constraints - Multi Objective Optimization – Mathematical Optimization Software – Development of Energy Optimization Model -Development of Scenarios – Sensitivity Analysis - Concept of Fuzzy Logic. [10]
4. **Project Management:** Project Preparation – Feasibility Study – Detailed Project Report - Project Appraisal – Social-cost benefit Analysis - Project Cost Estimation – Project Risk Analysis - Project Financing – Financial Evaluation. [10]
5. **Energy Policy:** 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). [10]

Course Outcome: Upon successful completion of this course, students should be able to:
- Know the energy prediction using various forecasting techniques.
- Develop optimization model for energy planning.
- Understand National and state energy policies.

Text Books:
1. S. Makridakis, Forecasting Methods and applications, John Wiley & Sons, 2nd Edition, 2002.
2. Yang X.S., Introduction to mathematical optimization: From linear programming to Metaheuristics, Cambridge International Science Publishing, 4th Edition, 2008.

Reference Books:
1. Austin H. Church, Centrifugal Pumps and Blowers, John Wiley and Sons, 4th Edition, 2013.

EE 19.509 **Power System and Smart Grid** **Total Lectures: 52**

4-0-0-4

Objective:
- To provide the students a systems perspective of modern electricity markets and a systems approach to address various issues faced by the electricity sector.
- To present the student a vision of how Smart Grid will transform the current electricity grid to a reliable and sustainable modern energy system.

Prerequisite: Transmission and Distribution, Power System Analysis.

1. **Supply Side and Demand Side of Electricity:** Basics of electricity, Fossil fuels and hydro power plants, Renewable and alternative energy, Supply curve, Load characteristics, Load curve and load duration curve, Demand side management. [11]
2. **Transmission and Distribution Network:** Physical law of electricity, AC vs. DC power flow, Optimal Power flow and unit commitment models, Distribution network basics. [10]
3. **Basic Elements of Smart Grid:** The origin of power grid, dependency on power grid, desirable features of power grid, reliability, security, economic, efficiency, environmental friendly, safety. [11]
4. **Key Characteristics of Smart Grid:** Demand-side participation, Impact of Smart Grid on reliability, Impact of Smart Grid on air pollutant emissions reduction. [10]
5. **Issues Related to Smart Grid:** Communication and sensing in a smart grid, smart grid threats, vulnerabilities, cyber security strategies. [10]

Course Outcome: Upon successful completion of this course, students should be able to:
- Gain Knowledge about the economic fundamentals of power systems and electricity markets.
- Understand the concepts of various components of Smart Grid, and their impacts on the energy industry, including renewable integration, demand side management, and greenhouse gas emission reduction.

Text Books:
1. Marco H. Balderas, Renewable Energy Grid Integration, Nova Science Publishers, New York, 4th Edition, 2009.
2. Nick Jenkin, Janaka Ekavayake, Wind Energy Generation Modeling and Control, Wiley-Blackwell, 4th Edition, 2009.

Reference Books:
1. AJ Wood and BF Wollenberg, Power Generation, Operation and Control, John Wiley & Sons, New York, 4th Edition, 2017.

EE 19.508 **Environmental Impact of Energy System** **Total Lectures: 52**

4-0-0-4

Objective: To achieve environmental improvements and know the environmental values and behavior.

Prerequisite: Power Plant Engineering.

1. **Impact of Energy Systems on Environment:** Environmental degradation due to energy production and utilization, Primary and Secondary pollution such as SOx, NOx, SPM in air, thermal and water pollution, depletion of ozone layer, global warming, biological damage due to environmental degradation. Sociological and Economical problems due to Thermal and other energy projects. Physiological, ecological and environmental and health problems due to energy plants. Methods of Environmental Impact Assessment. [12]
2. **Pollution Due To Thermal, Hydel and Nuclear Power Plants:** Potential sources of Pollution in thermal power plant, Air, water, land pollution due to estimation for thermal power plant. Environmental pollution limits guidelines for thermal power plant pollution control. Various pollution control equipments such as dust collector, bag filter, electrostatic separator, working principle and selection criteria, designing the pollution control system, methods and limitation. Water pollution in thermal power plant, physical and chemical methods of pollution control, Land pollution effect of land pollution, measurement of land pollution. Limitations and advantages of pollution control systems. Hydrothermal plant environmental assessment, hydrothermal plant and rehabilitation measures for hydrothermal plant. Nuclear power plants and environmental pollution, pollution control measures. Effect of Hydroelectric power stations on ecology and environment. [14]
3. **Industrial and Urban Waste & Waste Energy Recovery:** Industrial waste, Waste and effluent treatment, Waste as a source of energy: Industrial, domestic and solid waste as a source of energy. Pollution control: Causes, process and exhaust gases and its control, mechanism and devices for pollution control. [10]
4. **Environmental and Pollution Control Laws:** United Nations Framework Convention on Climate Change (UNFCC), Protocol, Conference of Parties (COP) 19 Clean Development Mechanism (CDM), Prototype Carbon Funds (PCF) Carbon Credits and it's trading, Benefits to developing countries, Building a CDM project. [10]
5. **Global Environmental Concern:** Global Environmental Issues, ozone layer depletion, Global Warming, Green House Gases Emission. [6]

Course Outcome: Upon successful completion of this course, students should be able to:

- Understand environmental effects and act accordingly to improve the environmental conditions globally.

Text Books:

1. W. K. Foell, Management of Energy Environment Systems, John Wiley and Sons, 6th Edition, 2013.
2. M.C. MacedoJr, Energy Management and Control Systems, John Wiley and Sons, 4th Edition, 2004.

Reference Books:

1. J. G. Rau, D.C. Wood, Environmental Impact Analysis Handbook, McGraw Hill, 7th Edition, 2005.
2. J. M. Fowler, Energy & Environment, McGraw Hill,, ERIC, 2nd edition, 2009.

EE 19.510 **Power System for Renewable Energy Sources** **Total Lectures: 52**
4-0-0-4

Objective: To know the grid integration of renewable energy sources, different machines, and power electronics devices uses in renewable energy power plants.

Prerequisite: Power System Analysis, Renewable Energy System.

1. **Introduction To Renewable Energy Grid Integration:** Concept of mini/micro grids, and smart grids. Review of synchronous generators, Introduction to power system stability problems: rotor angle stability, voltage stability and voltage collapse, classification of stability. Modelling of synchronous machines: transformations, synchronous machine representation in stability studies. [12]

2. **Introduction To Induction Machines:** Electrical characteristics, slip, speed torque characteristics etc. Self-excited induction generator, Constant speed Induction generators, Variable speed Induction generators, Doubly fed Induction generators. [10]

3. **Introduction To Power Electronic Devices:** AC/DC converters, PWM, THD. Permanent magnet synchronous generator, solar PV systems, fuel cell, aqua electrolizer. [10]

4. **Issues in Integration of Different Generators:** Issues in integration of synchronous generator based, induction generator based and converter based sources together. Network voltage management (discusses the issue of voltage levels). [10]

5. **Power Quality Management:** Voltage dips, harmonics and flickers. Frequency management. Influence of WECS on system transient response – IEEE standard and Polices. [10]

Course Outcome: Upon successful completion of this course, students should be able to:

- Analyze the power quality management in renewable power plants.

Text Books:
1. Marco H. Balderas, Renewable Energy Grid Integration, Nova Science Publishers, New York, 2009.
2. Nick Jenkin, Janaka Ekavayake, Wind Energy Generation Modeling and Control, Wiley-Blackwell, 2nd Edition, 2009.

Reference : Books:
1. AJ Wood and BF Wollenberg, Power Generation, Operation and Control, John Wiley & Sons, New York, 4th Edition, 2006.

ME-19.512 **Solar Refrigeration and Air-Conditioning** **Total Lectures: 52**
4-0-0-4

Objective:
- To learn the fundamental concepts about solar energy refrigeration and air-conditioning systems.
- To learn the fundamental concepts about solar energy refrigeration and air-conditioning systems.
- To study solar cooling, vapour absorption refrigeration and air-conditioning system, vapour compression systems with implementation techniques for detailed knowledge about solar refrigeration and air-conditioning systems

Prerequisite: Basic Thermodynamics

1. **Introduction** - Potential and scope of solar cooling - Types of solar cooling systems - Solar collectors and storage systems for solar refrigeration and air-conditioning – Refrigerants [10]

2. **Solar Cooling:** Need for solar cooling - Jet ejector solar cooling systems - Fuel assisted solar cooling systems – Solar thermo acoustic cooling and hybrid air-conditioning - Solar desiccant cooling systems – Advanced solar cooling systems. [10]

3. **Absorption Cooling:** Basics of absorption cooling - Principle of absorption cooling - Solar operation of vapour absorption refrigeration cycle - Open cycle absorption / desorption solar cooling alternatives – Lithium Bromide-Water absorption System – Aqua-ammonia absorption system – Intermittent absorption refrigeration System - Refrigerant storage for solar absorption cooling systems. [12]

4. **Vapour Compression Refrigeration:** Vapour compression refrigeration cycles - Rankine cycle - Sterling cycle based solar cooling systems- Thermal modeling for continuous and intermittent solar refrigeration and air-conditioning systems. [10]

5. **Implementation Techniques:** Photovoltaic powered refrigerator – Free cooling - Solar thermoelectric refrigeration and air-conditioning – Solar economics of cooling systems - Case studies. [10]

Course Outcome: Upon successful completion of this course, students should be able to:
- Know the fundamental concepts about solar energy refrigeration and air-conditioning systems.
- Implement the principles, theories and the materials used for solar cooling, vapour absorption refrigeration.

Text Books:
1. Rakosh Das Begamudre, Energy Conversion Systems, New Age International, 4th Edition, 2007.
2. Tom P. Hough, Solar Energy: New Research, Nova Publishers, 3rd Edition, 2006.

Reference Books:
1. Alefeld G. and Radermacher R., Heat Conversion Systems, CRC Press, 4th Edition, 2004.

EE 19.512 **Power Electronics for Renewable Energy Source** **Total Lectures: 52**

4-0-0-4

Objective:
- To impart knowledge on Standalone, Grid connected and Hybrid renewable energy systems.
- To understand the different types of Electrical Machines and Power Converters employed for renewable energy conversion systems

Prerequisite: Power Electronics, Renewable Energy System.

1. **Introduction:** Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission), Qualitative study of different renewable energy resources: Solar, wind, ocean, Biomass, Fuel cell, Hydrogen energy systems and hybrid renewable energy systems. [12]

2. **Electrical Machines For Renewable Energy Conversion:** Review of reference theory fundamentals-principle of operation and analysis: IG, PMSG, SCIG and DFIG. [8]

3. **Power Converters:** Solar: Block diagram of solar photo voltaic system, Principle of operation: line commutated converters (inversion-mode), Boost and buck-boost converters, selection of inverter, battery sizing, array sizing, Wind: three phase AC voltage controllers, AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid Interactive Inverters-matrix converters. [12]

4. **Analysis of Wind and PV Systems:** Stand-alone operation of fixed and variable speed wind energy conversion systems and solar system, Grid connection Issues, Grid integrated PMSG and SCIG Based WECS Grid Integrated solar system. [10]

5. **Hybrid Renewable Energy Systems:** Need for Hybrid Systems, Range and type of Hybrid systems, Case studies of Wind-PV, Maximum Power Point Tracking (MPPT). [10]

Course Outcome: Upon successful completion of this course, students should be able to:
- Understand the concepts of Standalone, Grid connected and Hybrid Energy System
- Understand different types of Electrical Machines and Power Converters employed for Renewable Energy Conversion Systems.

Text Books:
1. Leon Freris, David Infield, Renewable Energy in Power Systems, John Wiley & Sons, 2008.
2. Rashid .M. H, Power Electronics Hand book, Academic press, 1st edition, 2007.

Reference Books:
1. Rai. G.D, Non-Conventional Energy Sources, Khanna publishes, 2nd Edition, 2010.
2. Ali Keyhani, Design of Smart Power Grid Renewable Energy Systems, John Wiley & Sons, 4th Edition, 2011.
3. S. N. Bhadra, D. Kastha, Wind Electric Systems, Oxford University Press, 5th Edition, 2005.