Rural Energy Centre

Ph.D Course Work

Semester	Paper Code	Course Title	Credits	Total
Core Courses				
I	17REER0101	Solar & Wind Energy Technologies	4	
	17REER0102	Bio & New Renewable Energy Technologies	4	
	17REER0103	Renewable Integrated Power Systems	4	
	17APRR0101	Research Methodology	4	
II	17REER0204	Instrumentation & Control Systems for Renewable Energy Systems	4	
	17REER02SX	Specific course to be prescribed by the Doctoral Committee	4	24
	Seminar (3) Term Paper/Topical Research			
III Semester onwards	a) Project Planning including literature collection, finalisation of objectives and methodology b) Field / Lab Studies, Data collection, compilation of results, statistical analysis, results and final conclusion		4 32	
End of Program	Synopsis and thesis submission, final viva		6	

List of courses that are candidate centric (17REER02SX)

17REER02S1	Renewable Energy & Energy Conservation / Management

17REER0101 SOLAR & WIND ENERGY TECHNOLOGIES Credit: 4

Learning Objective:

Describe and demonstrate the application of Solar & Wind Energy Technologies for the societal needs

Learning Outcomes:

- ✓ Understand the physics of solar & Wind energy
- ✓ Design and Evaluate the Solar & Wind Devices for specific application
- ✓ Able to understand and optimize the solar & wind system for rural applications

UNIT I

Solar Radiation – Assessment of Radiation - Measurement of solar radiation – Pyranometer, pyrheliometer, Sunshine recorder. Solar time - Local apparent time (LAT), equation of time (E) Solar radiation geometry - Earth-Sun angles – Solar angles. Calculation of angle of incidence - Calculation of total solar radiation on horizontal and tilted surfaces. Prediction of solar radiation availability- Forecasting techniques -Analysis of Indian solar radiation data and applications Solar Energy Policies and Schemes

UNIT II

Solar systems for process heat production - Solar cooking – Performance and testing of solar cookers. Seawater desalination – Methods, solar still and performance calculations. Solar pond - Solar greenhouse. Solar thermal electric power plants based on parabolic trough, solar central receiver, parabolic dish-Stirling engine. Concentrated solar power using Fresnel lenses. Fundamentals of design calculations and analysis of solar power plants. Economic analysis. Necessity of storage for solar energy- Chemical energy storage - Thermal energy storage - Thermal Flywheels - Compressed air- Rechargeable batteries

UNIT III

Formation of a pn – junction - Space charge and internal field - Quasi - Fermi levels - The Shockley diode equation - Structure of a solar cell - The solar cell equation - Fill factor and maximum power - Various electron - hole-pair recombination mechanisms - Crystalline silicon

solar cells - Thin film solar cells: CIGS, Cite and a – silicon - Tandem solar cells - Dye - sensitized solar cells - Organic solar cells Device isolation & analysis - Ideal cell under illumination solar cell parameters short circuit current, open circuit voltage, fill factor, efficiency; optical losses; electrical losses, surface recombination velocity, quantum efficiency - measurements of solar cell parameters; I-V curve & L-I-V characteristics, internal Quantum yield measurements – Effects of series and parallel resistance and Temperature - Loss analysis

UNIT IV

Characteristics of the Atmospheric Boundary Layer- Stability of the Atmospheric Boundary Layer- Turbulence- Turbulence Intensity- Effect of Terrain on Wind Characteristics-General Description of the Wind-Influences on Airflow-Effects of Surface Roughness-siting in flat and complex terrain-buidling shelters-trees-depression –gap-passess .Wind resource Assessment-Measurement of wind: Ecological indicator, Anemometers and wind directions -Wind speed statistics: power available in the wind-Time and Frequency distribution, Mean wind speed and distribution of wind velocity -Statistical model for wind data analysis: Weibull distribution-Analysis of wind regimes - Local effects, wind shear, Turbulence and acceleration effects

UNIT V

Introduction- Wind Energy System- classification of wind turbines- Components: Blades, hub, nacelle-Gearbox, generator, brakes- Tower, foundation, control system- Drivetrain Components-Betzlimit -performance of wind machines- Power, Torque Speed Characteristics- repowering of wind turbines-micro siting Wind Energy System Economics-. Engineering Economics Basics-Wind Turbine Cost Analysis- Basics for Calculating the Costs of Electricity - Calculation of the electricity generation costs of a large-sized wind turbine - Financing Costs - Economic Analysis Methods - Simple Payback Period Analysis - Life Cycle Costing Methods - Cash Flow Method (CFM) - levelized cost of electricity (LCOE) - discount rate - net present value - real rate of return - depreciation cost – Pay Back -Economic Performance Sensitivity Analysis

REFERENCES

1. Duffie, J.A., and Beckman, W.A. Solar Energy Thermal Process, John Wiley and Sons, New York, Jui Sheng Hsieh, Solar Energy Engineering, Prentice-Hall, 2007.

2. Sukhatme S.P., Solar Energy, Tata McGraw Hills P Co., 3rd Edition, 2008.
3. M. Stix, The Sun, An Introduction, Second Edition, Springer 2002.
4. Nelson, The Physics of Solar Cells. Imperial College Press, 2003.
5. Rai, G.D., Solar Energy Utilization, Khanna Publishers, N. Delhi, 2010.
6. B.G. Streetman and S. Banerjee, Solid State Electronic Devices, Sixth Edition, Prentice Hall,2006.
7. Wind Electric Systems: S.N.Bhadra,D.Kastha, OXFORD university press, 2005.
8. Related MOOC Courses

17REER0102 BIO & NEW RENEWABLE ENERGY TECHNOLOGIES

Credits: 4

Learning Objective:

Describe and demonstrate the application of Solar & Wind Energy Technologies for the societal needs

Learning Outcomes:

- ✓ Understand the physics of solar & Wind energy
- ✓ Design and Evaluate the Solar & Wind Devices for specific application
- ✓ Able to understand and optimize the solar & wind system for rural applications

UNIT I

Introduction Classification of biofuels, liquid and gaseous Production processes Raw materials and products. Introduction to biological processes of transformation Bioreactor concepts Kinetics of microbial growth Enzymatic kinetics Bioenergetics of biological reactions. Transformation of the substrate in biomass Applications of batch, CSTR and plug flow reactors Concepts of biofilm kinetics and fixed biomass reactors Anaerobic digestion. Microbiology and kinetics Phases of anaerobic digestion Disintegration and hydrolysis; Acidogenesis; Acetogenesis; Methanogenesis Syntrophic relationships between species Relevant chemical equilibria IWA-ADM1 Model (Anaerobic Digestion Model No. 1) Anaerobic digestion. Environmental and operational conditions Temperature pH and alkalinity Nutrients requirement Toxics and inhibitors Solids and hydraulic retention time Organic loading rate Granulation of anaeroobic biomass

UNIT II

Direct Combustion, Technology of Biomass gasification, Pyrolysis and Liquefaction, Biomass Gasifiers: History, Principle, Design of Biomass Gasifiers, updraft gasifier, down draft gasifier, zero carbon biomass gasification plants, Gasification of plastic-rich waste, applications for cooking, electricity generation, Gasifier Engines, Operation of spark ignition and compression ignition engine with wood gas, methanol, ethanol and biogas, Biomass integrated

gasification/combined cycles systems. Kinetics of Biomass Gasification - Reaction Kinetics - Mechanism of Gasification

UNIT III

Fuel cell electrochemistry - Reaction rate - Butler Volmer equationimplications and use of fuel cell polarization curve - Conversion of chemical energy in electricity in a fuel cell. Type of fuel cells, fuel cell working principle – Design - Proton exchange membrane fuel cells - Design issues - High temperature fuel cells - SOFCMCFC - Comparison of fuel cell - Performance characteristics - Efficiency of leading fuel cell types. nano dimensional materials, classification of nanomaterials, bulk materials and nanomaterials – changes in bulk and nanomaterials of silicon, silver, gold. General methods of preparation of nanomaterials, thermal and thermo-electric properties of nano structures - modeling and metrology. Nanowires, nanostructures, nanocomposites

UNIT IV

Small Hydropower Systems - 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 V

Ocean Energy As An Alternative Energy Source - Various Forms of Ocean Energy - Ocean Energy Potential – Global Scenario - Ocean Thermal Energy Conversion- Tidal Energy- Estimation of Tidal Energy Geothermal- MHD – Open and Closed Cycle System – Topping Cycle – Seed Recovery - Thermionic- Thermoelectric energy conversion system - Lithium Iron Batteries – Characteristics – Alge - Micro Alge - Marine Alge– Economics Biodiesel from Alge

REFERENCES

1. Khanal, S.K. Bioenergy and biofuels from biowastes and biomass. Virginia: American Society of Civil Engineers, 2010. ISBN 9780784410899.

2. Mousdale, David M. Biofuels : biotechnology, chemistry, and sustainable development. Boca Raton: CRC Press, cop. 2008. ISBN 9781420051247.
3. Mata Álvarez, Joan. Biomethanization of the organic fraction of municipal solid wastes. London: IWA, 2003. ISBN 1900222140.
4. Rittmann, Bruce E; McCarty, Perry L. Environmental biotechnology : principles and applications. Boston [etc.]: McGraw-Hill, cop. 2001. ISBN 9780071181846.
5. Batstone, D. J. Anaerobic digestion model no. 1 / IWA Task Group for Mathematical Modelling of Anaerobic Digestion Processes. London: IWA Publishing, 2002. ISBN 9781900222785.
6. Municipal Solid Waste to Energy Conversion Processes: Economic, Technical, and Renewable Comparisons, by Gary C. Young, ISBN:9780470539675, Publisher: John Wiley & Sons, Publication Date: June 2010.
7. Detlef Stolten , "Hydrogen and Fuel Cells: Fundamentals, Technologies and Applications", 2010.
8. Related MOOC Courses

17REER0103 RENEWABLE INTEGRATED POWER SYSTEMS

Credits: 4

Learning Objective:

Describe and demonstrate the application of Solar & Wind Energy Technologies for the societal needs

Learning Outcomes:

- ✓ Understand the physics of solar & Wind energy
- ✓ Design and Evaluate the Solar & Wind Devices for specific application
- ✓ Able to understand and optimize the solar & wind system for rural applications

UNIT I

Introduction – Characterization of Electric Power Quality: Transients, short duration and long duration voltage variations, Voltage imbalance, waveform distortion, Voltage fluctuations, Power frequency variation, Power acceptability curves – power quality problems: poor load power factor, Non linear and unbalanced loads, DC offset in loads, Notching in load voltage, Disturbance in supply voltage –

UNIT II

Power quality standards. Single phase linear and non linear loads – single phase sinusoidal, non sinusoidal source – supplying linear and nonlinear load – three phase Balance system – three phase unbalanced system – three phase unbalanced and distorted source supplying non linear loads – convert of pf – three phase three wire – three phase four wire system.

UNIT III

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. Stand alone

operation of fixed and variable speed wind energy conversion systems and solar system- Grid connection Issues -Grid integrated PMSG, SCIG Based WECS, grid Integrated solar system

UNIT IV

Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Opportunities & Barriers of Smart Grid, Difference between conventional & smart grid, Concept of Resilient & Self Healing Grid, Present development & International policies in Smart Grid. Case study of Smart Grid. CDM opportunities in Smart Grid. Introduction to Smart Meters, Real Time Prizing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid, Smart Sensors, Home & Building Automation, Phase Shifting Transformers.

UNIT V

Micro grids and Distributed Energy Resources: Concept of micro grid, need & applications of micro grid, formation of microgrid, Issues of interconnection, protection & control of microgrid. Integration of renewable energy sources. Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring.

REFERENCES

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

17REER0204 INSTRUMENTATION & CONTROL SYSTEMS FOR RENEWABLE ENERGY SYSTEMS

Credits: 4

Learning Objective:

Describe and demonstrate the application of Solar & Wind Energy Technologies for the societal needs

Learning Outcomes:

- ✓ Understand the physics of solar & Wind energy
- ✓ Design and Evaluate the Solar & Wind Devices for specific application
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UNIT I

Measurement of temperature, pressure, flow and level – application - selection – calibration methods. Ion selective electrodes - Gas & Liquid Chromatography - Oxygen analyzers for gas and liquid –CO,CO_2 ,NO and SO Analyzers- Hydrocarbon and H_2S Analyzers – Dust, smoke, Toxic gas and radiation monitoring. – Pyranometer – Pyrheliometer – Sunshine Recorder – Alphatometer

UNIT II

Importance of error analysis - Uncertainties, precision and accuracy in measurement - Random errors - Distributions, mean, width and standard error - Uncertainty as probability - Gaussian and Poisson probability distribution functions, confidence limits, error bars, and central limit theorem - Error propagation - single and multi-variable functions, propagating error in functions - Data visualization and reduction - Least square fitting of complex functions

UNIT III

Transducer - Variable Capacitive Transducer – Capacitor Microphone - Piezo Electric Transducer – Variable Inductive transducer – LVDT, RVDT DVM, DMM – Storage Oscilloscope. Comparison of Analog and Digital Modes of operation, Application of

measurement system, Errors. Measurement of R, L and C, Wheatstone, Kelvin, Maxwell, Anderson, Schering and Wien bridges Measurement of Inductance, Capacitance, Effective resistance at high frequency, Q-Meter.

UNIT IV

Evolutions of PLCs – Programmable Controllers – Architecture – Comparative study of Industrial PLCs. –PLC Programming:- Ladder logic, Functional block programming, Sequential function chart, Instruction list and Structured text programming. SCADA:- Remote terminal units, Master station, Communication architectures and Open SCADA protocols

UNIT V

Characteristic of ON-OFF, P, P+I, P+D and P+I+D control modes – Digital PID algorithm – Auto/manual transfer - Reset windup – Practical forms of PID Controller – PID types Fuzzy Controller -Evaluation criteria – IAE, ISE, ITAE and ¼ decay ratio. Tuning: - Process reaction curve method:- Z-N and Cohen-Coon methods, Continuous cycling method and Damped oscillation method – optimization methods – Auto tuning –Tuning PID Controller using Fuzzy Logic.

REFERENCES:

1. Anderson N.A., Instrumentation for Process Measurement and Control, Chilton company, 1980.
2. Deoblin E.O., Measurement System Application and Deisgn, McGraw Hill, 1990.
3. Neubert ,HKP, Instrument Transducers, Oxford University Press, 1999.
4. B.G.Liptak, “Instrumentation Engineers Handbook (Process Measurement & Analysis)”, Fourth Edition, Chilton Book Co, CRC Press, 2005.
5. Al.Sutko,Jerry.D.Faulk, “Industrial Instrumentation”, Delmar publishers, 1996.
6. Paul Gruhn, P.E., CFSE and Harry Cheddie, P.E., “Safety Instrumented Systems: Design, Analysis, and Justification”, 2nd Edition, ISA,2006.
7. Safety - ANSI/ISA84.00.01-2004, Part 1: Framework, Definitions, System Hardware and Software Requirements; ANSI/ISA84.00.01-2004, Part 2: Functional Safety: Safety

Instrumented Systems for the Process Industry Sector; ANSI/ISA84.00.01-2004, Part 3: Guidance for the Determination of the Required Safety Integrity Levels-Informative.

8. Standards - ANSI/ISA-75.01.01 -2002 (60534-2-1 Mod): Flow Equations for Sizing control Valves; ISA84 Process Safety Standards and User Resources, Second Edition, ISA, 2011; ISA88 Batch Standards and User Resources, 4th Edition, ISA, 2011.
9. Documentation Standards - ANSI/ISA5.4-1991 - Instrument Loop Diagrams; ANSI/ISA5.06.01-2007 - Functional Requirements Documentation for Control Software Applications; ANSI/ISA20-1981 - Specification Forms for Process Measurement and Control Instruments, Primary Elements, and Control Valves.
10. Related MOOC Courses