

**Course Title: Renewable Energy Systems**

**Course Code: EPEG 424**

**Credit Hours: 3**

**Course Description:**

The course intends to impart foundation for the renewable energy sources for electrical power systems, their integration and sustainability.

**Course Contents:**

**Unit 1: Renewable Energy Sources**

World Energy Supplies, Energy Use and potentials, energy problems, need of renewable energy, different types of renewable energy sources, barriers to the use of renewable energy sources, sustainability of renewable energy sources

**Unit 2: Solar Radiation and Measurement**

The Solar Spectrum, the Earth's Orbit, Altitude Angle of the Sun, Solar Position at any Time of Day, Sun Path Diagrams and Shading Analysis, Solar Time and Civil (Clock) Time, Sunrise and Sunset, Clear Sky Direct-Beam Radiation, Total Clear Sky Insolation on a Collecting Surface, Direct-Beam Radiation, Diffuse Radiation, Reflected Radiation, Tracking Systems, Monthly Clear-Sky Insolation, Solar Radiation Measurements, Solar thermal Systems

**Unit 3: Solar Photovoltaic System**

Introduction of photovoltaic systems and application, Solar Photovoltaic cells and technologies, a generic photovoltaic cell, electrical characteristics of solar cell, Photovoltaic cell to modules to array, I-V Curve of module, environmental impact on solar module, Shading impacts and mitigation, components of a photovoltaic systems, Balance of System for PV system ( Battery, Charge controller, dc to dc converter, Inverter and cables), Stand alone PV system sizing for dc and ac loads, PV system sizing for water pumping, grid connected PV system

**Unit 4: Wind Energy Conversion System**

Introduction to wind energy system, Types of Wind Turbines, Power in the Wind, Impact of Tower Height, Maximum Rotor Efficiency, Wind turbine generators, average power in wind, estimate of wind turbine energy, wind farms, Wind Turbine Power Curve, Speed Control for Maximum Power, Standalone Wind Energy Conversion System sizing, Environmental Impacts

**Unit 5: Biogas, Biomass and Biofuels**

Biogas Generation and stages of anaerobic digestion, factors affecting biogas generation, materials used for biogas generation, Biogas plants types, design consideration of a biogas plant, construction of a biogas plant, biogas electrification, system components for biogas electrification, system sizing for biogas electrification, landfill gas, Technologies for use of solid biomass, improved cook stoves, briquettes, gassifiers, types of liquid biofuels, sources of liquid biofuels, production of liquid bio-fuels

### **Unit 6: Geothermal, Wave, Tide and Ocean Thermal Energy Conversion Systems**

Physics of geothermal resources, technologies for geothermal resource exploitation- geothermal electricity, geothermal heat pump, Wave energy principles, wave capture systems, oscillating water column, wave profile devices, tide energy principles, power generation for tides, Ocean thermal energy conversion (OTEC) principles, electricity generation using OTEC

### **Unit 7: Energy Storage Systems**

Batteries and types, Ultra-capacitors, Flywheels, Superconducting Magnetic Storage Systems, Pumped hydroelectric energy storage, Compressed air energy storage, storage heat, fuel cells

### **Unit 8: Hybrid Renewable Energy Systems**

Design and sizing of hybrid renewable energy system using solar photovoltaic system, wind turbine, biogas generator and storage system for isolated electrical system, micro grid and its issues

### **Unit 9: Grid Integration of Renewable Energy Sources**

Requirements for grid interconnection, limits on operational parameters,,: voltage, frequency, THD, response to grid abnormal operating conditions, islanding issues; Impact of grid integration with renewable energy sources on existing power system: reliability, stability and power quality issues, Standards for interconnecting renewable energy sources to electric power system.

### **Unit 10: Economics and Sustainability of Renewable Energy Sources**

Energy economics, Cost Comparison of different renewable energy sources, Levelized cost of energy (LCOE), sensitivity analysis, renewable energy marginal cost and cost of conservation, production tax credits, green power market, renewable feed in tariffs, energy subsidies, socio-economic impact, environmental policies, sustainability development goal, sustainability policies, sustainable designs and options, energy efficiency, Smart management of energy sources for sustainability

### **References:**

1. Boyle G., “*Renewable Energy Power for a Sustainable Future*”, Oxford University Press
2. Twidell J. , Weir T., “*Renewable Energy Resources*” , Taylor and Francis
3. Masters G. M., “*Renewable and Efficient Electric Power Systems*”, Wiley
4. Farret F. A., Simoes M. G., “*Integration of Alternative Sources of Energy*”, John Wiley and Sons
5. Bollen M.H.J., Hassan F., “*Integration of Distributed Generation in the Power System*”, IEEE Press Series on Power Engineering. Wiley. Hoboken 2011
6. IEEE Standard 1547 for Interconnecting Distributed Resources with Electric Power Systems

### **Evaluation:**

In-Semester Evaluation: 50%

End-Semester Evaluation: 50%