

UNIT I

Chapter 1 : Solar Energy Principles

1-1 to 1-45

Syllabus : Present solar energy scenario, world energy futures, governing bodies (self-study), solar radiations and its measurements, solar constant, solar radiation geometry, solar radiation data, estimation of average solar radiation, solar radiation on tilted surface.

1.1	Energy and Power.....	1-1
1.1.1	Primary and Final Energy Consumption.....	1-1
1.2	Classification of Energy Sources.....	1-1
1.2.1	Primary and Secondary Energy Sources	1-2
1.2.2	Commercial and Non-Commercial Energy Sources.....	1-2
1.2.3	Renewable (Non-Conventional) or Alternate and Non Renewable (Conventional) Energy Sources	1-2
1.3	Global Primary Energy Reserves.....	1-2
1.4	Global Energy Consumption	1-3
1.5	Reserves and Production of Energy in India.....	1-4
1.5.1	Sector wise Energy Consumption in India.....	1-6
1.5.2	Installed Capacity of Conventional and Non Conventional Energy Sources in India.....	1-6
1.5.3	Present Status of Power Generation in Maharashtra.....	1-7
1.6	Non Conventional Energy Sources	1-8
1.6.1	Need to Develop Non-conventional OR Renewable Energy of Sources	1-8
1.6.2	Non-conventional Energy Sources Relevant to India.....	1-8
1.6.3	Merits and Demerits of Renewable form of Energy	1-9
1.7	Role of Important Government Organization in Power Sector.....	1-10
1.7.1	Role of MNRE.....	1-11
1.7.2	Initiatives Taken by Govt. of India to Develop Renewable Energy Sources	1-11
1.8	Introduction to Solar Radiations	1-12
1.9	Structure of the Sun	1-13
1.9.1	Core (0 to 0.23 R).....	1-14
1.9.2	Radiation Zone (0.23 R to 0.7 R)	1-14
1.9.3	Convection Zone (0.7 R to 1.0 R).....	1-14
1.9.4	Photosphere	1-14
1.9.5	Reversing Layer	1-14
1.9.6	Chromospheres.....	1-14
1.9.7	Transition Layer.....	1-15
1.9.8	Corona.....	1-15
1.9.9	Sun-Earth Relationship	1-15
1.10	Composition of Solar Radiations (Terrestrial and Extra Terrestrial Radiations)	1-15
1.10.1	Terrestrial Radiation	1-15
1.10.2	Extra Terrestrial Radiation.....	1-15
1.10.3	Spectral Distribution of Solar Radiation.....	1-16
1.11	Solar Radiation at the Earth's Surface (Terrestrial Radiation) (a) Beam Radiation (b) Diffuse Radiation (c) Global Radiations	1-16

1.11.1	Beam Radiations (I_b).....	1-16
1.11.2	Diffuse Radiations (I_d) (Scattered Radiations).....	1-17
1.11.3	Global Radiations (I_g) or Total Radiations (I_T).....	1-17
1.11.4	Air Mass.....	1-17
1.12	Solar Constant (I_{SC}).....	1-18
1.12.1	Variation of Solar Constant	1-18
1.13	Solar Radiation Geometry or Basic Sun-Earth Angles.....	1-18
1.14	Tilt Factor (T_b).....	1-24
1.15	Daily Average Global Radiation	1-26
1.16	Measurement of Solar Radiations	1-27
1.16.1	Pyranometers	1-27
1.16.2	Pyrheliometer	1-28

UNIT II

Chapter 2 : Solar Thermal Systems and Applications

2-1 to 2-44

Syllabus : Types of solar thermal collector, flat plate collector analysis, evacuated tube collectors (ETC) analysis, its design and application, solar air heaters and its types, solar distillation.

Solar concentrating collectors : Types - line and point concentrator, theory of concentrating collectors, parabolic trough collector, parabolic dish collector, solar tower, concentrated Fresnel linear receiver (CFLR).

2.1	Introduction.....	2-1
2.1.1	Types of Solar Collectors	2-1
2.2	The Liquid Flat Plate Collector	2-2
2.2.1	Flat Plate Solar Air Heater.....	2-3
2.2.2	Advantages of Flat Plate Collectors	2-3
2.2.3	Evacuated Tube Solar Heater or Evacuated Tube Collector (ETC).....	2-3
2.2.4	Difference between Liquid and Air Flat Plate Collectors	2-4
2.3	Construction and Materials for Flat Plate Collectors	2-4
2.3.1	Absorber Plate and Tubes.....	2-5
2.3.2	Fixing of Absorber Plate and Tubes (Types of flat plate collectors).....	2-5
2.3.3	Thermal Insulation.....	2-6
2.3.4	Transparent Cover Plates	2-6
2.3.5	Casing or Container.....	2-6
2.3.6	Selective Surface and Selective Coatings.....	2-7
2.4	Performance Analysis of Flat Plate Collectors under Steady State Conditions	2-7
2.4.1	Instantaneous Collection Efficiency, η_i and Hourly Collection Efficiency, η_h	2-8
2.4.2	Collector Aperture Area (A_a)	2-9
2.4.3	Collector Gross Area (A_c)	2-9
2.4.4	Stagnation Temperature.....	2-9
2.4.5	Transmissivity of the Cover System	2-9
2.4.5.1	Transmissivity based on Reflection and Refraction	2-9
2.4.5.2	Transmissivity based on Absorption (τ_a).....	2-10
2.4.6	Transmissivity for Diffuse Radiation	2-11

2.4.7	Variation of Transmissivity with Angle of Incidence	2-11
2.4.8	Losses in Flat Plate Collector.....	2-11
2.5	Testing of Solar Collectors	2-12
2.5.1	Main Purposes of Testing.....	2-12
2.5.2	Testing Methods	2-12
2.5.3	Testing Procedures	2-13
2.6	Effect of Various Parameters on Performance of Collectors.....	2-14
2.7	Limitations of Flat Plate Collectors	2-15
2.8	Concentrating Type Collectors	2-20
2.8.1	Advantages of Solar Concentrators	2-21
2.8.2	Disadvantages of Solar Concentrators.....	2-21
2.9	Types of Solar Concentrating Collectors.....	2-21
2.10	Focusing Type Concentrators	2-22
2.10.1	Parabolic Trough Reflector.....	2-22
2.10.2	Mirror Strip Reflector Type Concentrating Collector	2-23
2.10.3	Fresnel Lens Concentrating Collector.....	2-24
2.10.4	Paraboloid Dish Collector.....	2-24
2.11	Non-Focussing Type Concentrators.....	2-25
2.11.1	Flat Plate Collector with Plane Reflector	2-25
2.11.2	Compound Parabolic Concentrator (CPC)	2-26
2.12	Central Tower Receiver Using Heliostat Mirrors	2-27
2.13	Advantages and Disadvantages of Concentrating Collectors over Flat plate Collectors	2-27
2.14	Selection of Materials	2-28
2.15	Performance Analysis of Concentrators.....	2-28
2.16	Optical Losses	2-32
2.17	Economics of Solar Heating System.....	2-33
2.17.1	Calculations for Payback Period of the Solar Heating System	2-33
2.17.2	Life Cycle Cost Analysis	2-34
2.18	Solar Distillation.....	2-35
2.19	Types of Solar Stills.....	2-36

UNIT III

Chapter 3 : Solar Photovoltaic and Applications

3-1 to 3-37

Syllabus : Forming the PN junction solar cells and its applications, structure of a solar cell, types of modules, PV array, solar cell equation, Fill factor and maximum power, Grid aspects of solar power, equipment used in solar photovoltaic plants, power conditioning Equipment-inverters, regulators, other Devices; System Analysis Design procedure, Design constraints, other considerations.

3.1	Introduction of Solar Photovoltaic System (SPV)	3-1
3.2	Advantages and Disadvantages of Solar Photovoltaic System	3-1
3.2.1	Advantages of SPV Systems	3-1
3.2.2	Disadvantages of Solar Photo Voltaic Systems	3-1
3.3	Applications of Solar PV Systems	3-2
3.4	Basics of Photovoltaics	3-2

3.4.1	Photovoltaic Materials	3-2
3.4.2	Basic Principle of Operation	3-2
3.5	Solar Photovoltaic Cell Materials.....	3-5
3.6	Principle of Operation of Photovoltaic (PV) Cell.....	3-5
3.7	Performance of Cell (I-V Characteristics).....	3-6
3.8	Solar Cell Efficiency	3-8
3.9	Factors Affecting the Efficiency of Solar Cell i.e. The Electrical Design of Solar PV System.....	3-9
3.9.1	Sun Intensity.....	3-9
3.9.2	Sun Angle.....	3-9
3.9.3	Shadow Effect	3-10
3.9.4	Temperature Effect.....	3-10
3.9.5	Effect of Climate	3-10
3.9.6	Electrical Load Matching	3-10
3.9.7	Sun Tracking; Peak Power Point Operation.....	3-10
3.10	Solar Cell Technologies	3-11
3.10.1	Mono-Crystalline Silicon Cell.....	3-11
3.10.2	Poly Crystalline Silicon Cell.....	3-12
3.10.3	Ribbon Silicon Cell	3-12
3.10.4	Thin Film Solar Cell [Non-Silicon Cell]	3-13
3.11	Solar Photovoltaic System	3-14
3.11.1	Photovoltaic Array	3-14
3.11.2	Inverter	3-15
3.11.3	Energy Storage.....	3-16
3.11.4	System Charge Control (Battery Controllers).....	3-17
3.11.5	Balance of Systems and Components	3-17
3.12	Types of Solar Photovoltaic Systems.....	3-17
3.12.1	Stand Alone System.....	3-18
3.12.2	Grid Connected Systems	3-20
3.13	Solar Pumping.....	3-21
3.13.1	Major Components of Solar Pumping System	3-22
3.13.1.1	Solar Panels.....	3-22
3.13.1.2	Mounting of the Solar Arrays	3-22
3.13.1.3	Solar Pumps.....	3-23
3.13.1.4	Types of Pumps	3-23
3.13.1.5	Water Storage Systems	3-23
3.14	Manufacturing Methods of Solar Cells	3-24
3.15	Design of Typical Solar Photovoltaic System.....	3-24
3.16	Balance of Solar (BOS) PV System	3-27
3.17	Power Conditioning Equipments	3-28
3.17.1	Battery	3-28
3.17.2	Battery Charge Controller (BCC).....	3-29
3.17.3	Power Conditioning Equipment.....	3-29

3.17.4 DC to DC Converters.....	3-30
3.17.5 Charge Controllers	3-30
3.17.6 Concept of MPPT	3-31
3.17.7 Solar Photovoltaic System Design Procedure.....	3-32
3.17.8 Design Constraints of SPV Systems	3-33

UNIT IV

Chapter 4 : Case Study on Solar Energy Applications

4-1 to 4-48

Syllabus :

Case study 1 : Design of solar food drier for domestic purpose referring existing system

Case study 2 : Design of parabolic dish solar cooker for domestic purpose referring existing system

Case study 3 : Design of solar photovoltaic system for domestic purpose referring existing system

4.1 Design of Solar Food Drier for Domestic Purpose Referring Existing System	4-1
4.2 Design of Parabolic Dish Cooker for Domestic Purpose Referring Existing System	4-11
4.2.1 Parabolic Geometry for the Design of Parabolic Dish Cooker	4-13
4.2.2 Parameter Characterising the Thermal Performance of the Parabolic Dish Solar Cooker	4-14
4.2.3 Design and Calculations without Considering Gravimetric and Volumetric Rice-water Ratios.....	4-17
4.3 Design of Solar Photovoltaic System for Domestic Purpose Referring Existing System.....	4-24
4.3.1 Introduction.....	4-24
4.3.2 Design Methodology for Solar Photovoltaic System for Domestic Purpose	4-26
4.3.3 Energy Flow Diagram for Designing a Stand-alone PV System with Battery Backup and AC or DC Load.....	4-31

UNIT V

Chapter 5 : Wind Energy

5-1 to 5-41

Syllabus : Principle of wind energy conversion; Basic components of wind energy conversion systems; various types and their constructional features; design considerations of horizontal and vertical axis wind machines : analysis of aerodynamic forces acting on wind mill blades and estimation of power output; wind data and site selection considerations, wind energy potential and installation in India.

5.1 Introduction.....	5-1
5.2 Causes of Wind	5-1
5.3 Principle of Wind Power (Momentum Theory)	5-2
5.3.1 Maximum Power.....	5-3
5.3.2 Ideal or Maximum Theoretical Efficiency, $\eta_{\max}$	5-5
5.3.3 Torque and Axial Thrust on Blades	5-5
5.4 Advantages and Disadvantages of Wind Energy	5-14
5.4.1 Block Diagram of Wind Energy Conversion System (WECS).....	5-15
5.4.2 Applications of Wind Energy	5-15
5.5 Wind Data and Energy Estimation	5-15
5.6 Classification of Wind Energy Conversion Systems (WECS)	5-16
5.6.1 Horizontal Axis Wind Turbines (HAWT)	5-17
5.6.2 Vertical Axis Wind Turbine (VAWT)	5-18
5.7 Horizontal Axis Wind Turbine (HAWT) Generator.....	5-19

5.7.1	Yaw Pitch Control	5-19
5.8	Vertical Axis Wind Turbine (VAWT)	5-20
5.8.1	Comparison of Horizontal and Vertical Axis Wind Mills	5-21
5.9	Performance of Wind Mills	5-21
5.9.1	Dependence of Power Coefficient, C_p on Tip Speed Ratio, λ	5-23
5.9.2	Dependence of Solidity, γ on Tip Speed Ratio, λ	5-23
5.10	Site Selection.....	5-24
5.11	Design Considerations in Blade Design	5-26
5.11.1	Nomenclature Related to Aerofoil Blades	5-26
5.11.2	Cross-section of Rotor Blade	5-26
5.11.3	Lift and Drag	5-27
5.11.4	Blade Sections.....	5-28
5.11.5	Tower Height	5-29
5.11.6	Number of Blades	5-29
5.11.7	Magnus Effect.....	5-29
5.12	Methods of Overcoming Fluctuations of Power	5-29
5.13	Design of Wind Turbine Rotor	5-30
5.13.1	Thrust on Turbine Rotor	5-31
5.13.2	Torque on Turbine Rotor	5-31
5.13.3	Effect of Speed of Wind Stream Variation (Cut-In and Cut-Out Speed)	5-32
5.13.4	Factors Affecting the Design of Wind Turbine.....	5-33
5.14	Offshore Wind Energy System	5-33
5.14.1	Advantages and Disadvantages of Offshore Wind Farms Compared Onshore Wind Farms	5-33
5.15	Present Status and Installations of Wind Energy in India	5-34
5.16	Wind Energy Conversion System (WECS) for Wind Farms and other Purposes	5-36
5.17	Pollution from Wind Energy	5-37

UNIT VI

Chapter 6 : Case Study on Windmill Design

6-1 to 6-33

Syllabus : Case study on designing miniature windmill for domestic purpose referring existing system

6.1	Case Study on Designing Miniature Windmill for Domestic Purpose Referring Existing System	6-1
6.1.1	Introduction	6-1
6.1.2	Classification of Wind Turbines	6-1
6.1.3	General Expression for Power in Wind	6-2
6.1.4	Concept of moving HAWT Rotor Blade	6-4
6.1.5	Wind Turbine Aerodynamics	6-5
6.1.6	Wind power extraction using Betz model of expanding air stream tube	6-9
6.2	Design Process for Miniature Windmill.....	6-16

