CBCS SCHEME

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18EE731

Seventh Semester B.E. Degree Examination, Feb./Mar. 2022
Solar and Wind Energy

Time: 3 hrs. Max. Marks: 100

Note: *Answer any FIVE full questions, choosing ONE full question from each module.*

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Explain about the importance and salient features of Non – Conventional Energy Sources. **(10 Marks)**

b. How the Energy Audit is classified? Explain each one clearly. **(10 Marks)**

OR

2 a. What are the necessity of Energy Storage? Also explain about energy storage device specifications. **(10 Marks)**

b. How the Solar radiations are depleted? **(05 Marks)**

c. With neat diagram, explain about Extraterrestrial and Terrestrial Radiations. **(05 Marks)**

Module-2

3 a. What are the different instruments used to measure the solar radiation data? Explain each with neat diagram. **(10 Marks)**

b. With neat diagram, explain the following :
i) Angle of Latitude (ϕ) ii) Surface Azimuth angle (γ) iii) Zenith Angle (θ_z)
iv) Inclination angle (α). **(10 Marks)**

OR

4 a. With neat diagrams, explain the working of : i) Solar water heater ii) Solar cookers. **(10 Marks)**

b. Explain with neat sketches, about Solar Passive Space heating and Cooling systems. **(10 Marks)**

Module-3

5 a. What are the important points to be considered for maximizing the Solar PV output? **(05 Marks)**

b. How you can construct Solar cell, Module and Array? Explain with neat diagram. **(10 Marks)**

c. Briefly explain about Maximum Power Point Trucker. **(05 Marks)**

OR

6 a. With neat block diagrams, explain about Solar PV systems and explain its applications. **(10 Marks)**

b. What is Balance of System Components? Briefly explain about individual components. **(10 Marks)**

Module-4

7 a. Write a brief note on the following :
i) Wind energy site selection considerations ii) The nature of the wind. **(10 Marks)**

b. What are the factors influence the cost of wind energy generation? **(05 Marks)**

c. Explain about Economics of wind energy. **(05 Marks)**

OR

8 a. Explain the following : i) Wind Energy Conversion ii) History of Wind Energy. **(10 Marks)**

b. What are the Environmental benefits and problems of Wind Energy? **(10 Marks)**

Module-5

9 a. What are the different Wind Energy Conversion System? Explain neatly. **(10 Marks)**

b. Explain the following :
i) Applications of Wind Energy ii) Environmental Aspects of Wind Energy. **(10 Marks)**

OR

10 a. What are the advantages and disadvantages of Wind Energy Conversion System? **(10 Marks)**

b. Explain the following :
i) Types of Wind Machines ii) Performance of Wind Machines. **(10 Marks)**

* * * * *

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1 a)

1.9 SALIENT FEATURES OF NON-CONVENTIONAL ENERGY SOURCES

Merits

1. Non-conventional sources are available in nature free of cost.
2. They produce no or very little pollution. Thus, by and large, they are environment friendly.
3. They are inexhaustible.
4. They have a low gestation period.

Demerits

1. In general, the energy is available in dilute form from these sources.
2. Though available freely in nature, the cost of harnessing energy from non-conventional sources is generally high.
3. Availability is uncertain; the energy flow depends on various natural phenomena beyond human control.
4. Difficulty in transporting such forms of energy.

1b)

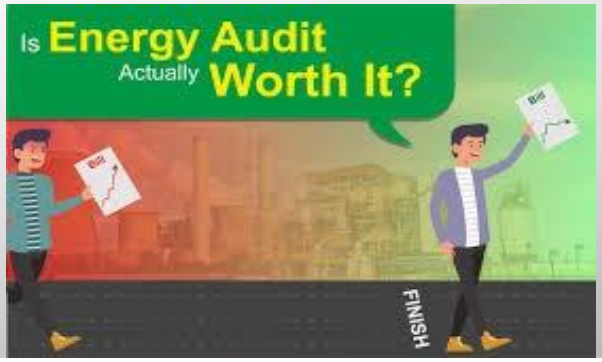
ENERGY AUDIT

- It is systematic approach for decision making in the area of energy management
- Industrial energy audit is effective tool in defining & pursuing comprehensive energy management programe
- Audit will help us to find the area where waste can occur
- It is classified as
  - **1. Preliminary energy audit**
  - Establish energy consumption in organization
  - Estimate the scope for saving
  - Identify most likely& easiest area for attention
  - Identify saving
  - Set reference point
  - Identify area for more detailed study

- **2.Targeted energy audit**
  - Based on the outcome of preliminary audit results
  - Provide detailed analysis on specific target project
- **3. Detailed energy audit**
  - Detailed study on energy saving and costs
  - ***Phase I : Preaudit phase***
  - Resources planning
  - Walk through audit
  - Informal interviews
  - Organise instrument and time frame
  - Macro data collection
  - Familiarisation of process
  - First hand observation and assessmen
  - Conduction of brief meeting
  - Organise cooperation awareness programme
  - Issue questionnaire to all heads
  - Orientation and awareness creation

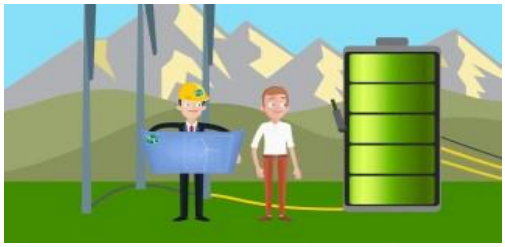
- **Phase II: audit phase activities**
  - Primary data gathering
  - Process flow diagram
  - Conduct monitoring survey and historic data analysis
  - Base line data collection
  - Prepare all service utilities system diagram
  - Design operating data and schedule electricity bill
  - Carry out survey of motor and protective devices
  - Conduct trial experiment for selected devices
  - Boiler efficiency trial
  - Furnace: trial equipment performance experiment
  - Identify and develop energy conservation opportunities
  - Identify and consolidate energy conservation measure
  - Use brainstorm & value analysis technique for new and efficient technology
  - Perform cost benefit analysis
  - Report presentation to top management

- **Phase III Post Audit Phase Activities**
  - Assist and implement energy conservation measure(ECM)
  - Make schedule for implementation
  - Follow up and perform periodic review



2a)

ENERGY STORAGE



- **INTRODUCTION**
- In contrast to fossil fuel & nuclear fuel based energy initial input power of renewable energy source is out of control
- There are problem in matching supply & demand in time domain.
- Energy storage can be defined as means of storing energy in a readily recoverable form when the supply is exceed the demand for use at other times
- Energy storage generally applies secondary energy rather than primary energy
- Various energy devices can be compared on the basis of ragone charts

- Vertical axis: how much energy is available
- Horizontal axis: how quickly energy can be derived

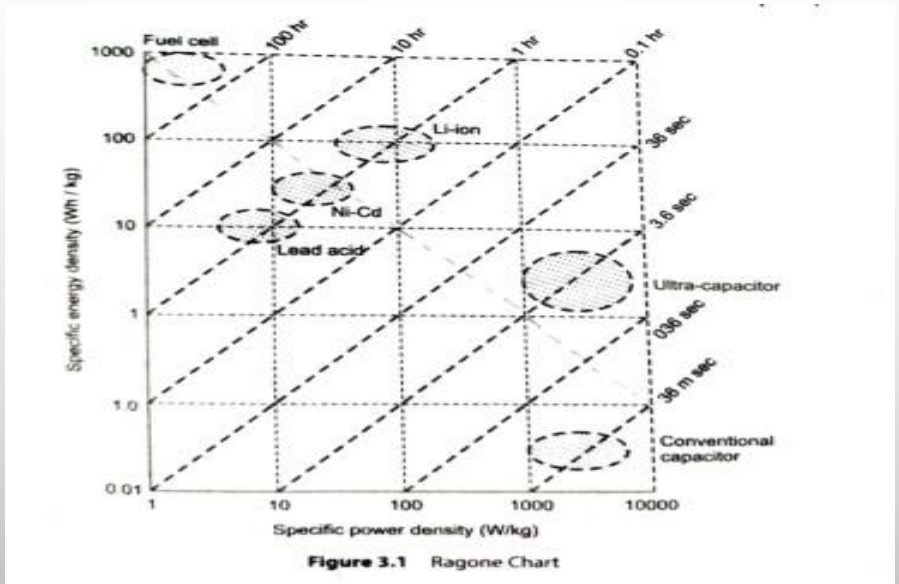


Figure 3.1 Ragone Chart

NECESSITY OF ENERGY STORAGE

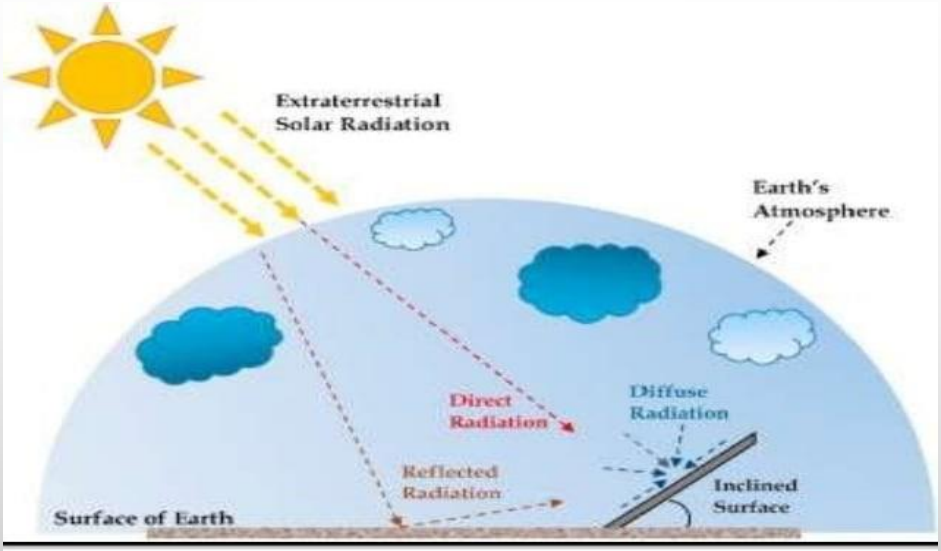
- Effective utilization **of intermittent and variable energy sources** such as solar, wind etc often require energy storage
- Location of power generation is **far from load center**. Both storing energy & transporting it economically to a load center
- Electrically propelled vehicle require some form of energy storage. Since **vehicle carry the energy supply** storage system must be transportable
- Energy storage is required for **load levelling** to reduce overall cost of generating electrical power

2c)

EXTRATERRESTRIAL AND TERRESTRIAL RADIATION

- Intensity of solar radiation keeps on attenuating as it propagate away from the surface of the sun though wavelength remain unchanged
- Extraterrestrial radiation
  - Solar radiation incident on outer atmosphere of the earth
  - The extraterrestrial radiation deviates from solar constant value due to 2 reason
  - 1. Variation in the radiation emitted by sun itself
  - Variation due to this reason is less than 15% with different periodicities
  - 2. Variation of earth sun distance arising from earths slightly elliptic path
  - Variation due to this reason is 3%

EXTRATERRESTRIAL AND TERRESTRIAL RADIATION



$$I_{ext} = I_{sc}\,[1 + 0.033 \cos (360\, n/365)]\ \mathrm{W/m^2}.$$

- n: is day of year starting from January 1
- Extraterrestrial radiation being outside the atmosphere is ***not affected by change in atmospheric condition***
- Due to atmospheric condition scattering will happen, a fraction of scattered radiation is reflected back to space while remaining is directed downwards
- Solar radiation that reaches earth surface after passing through earth atmosphere is known is known terrestrial radiation
- **Solar irradiation**
  - The terrestrial radiation expressed as energy per unit time per unit area(W/m^2)
- **Solar insolation**
  - Solar radiation energy received on a given surface area in given time(J/m^2)

3a)

Measurement of solar radiation

1. **PYRANOMETER**
   - Used to measure global radiation
   - For both horizontal and inclined surface
   - When shaded from beam radiation, it measure diffuse radiation only.
2. **PYRHELIOMETER**
   - To measure beam radiation
   - By using long and narrow tube
   - Used at nominal incidence.
3. **SUNSHINE RECORDER**
   - Measure sunshine hours in a day

2

Pyranometer

Sunshine recorder

Pyrheliometer

PYRANOMETER

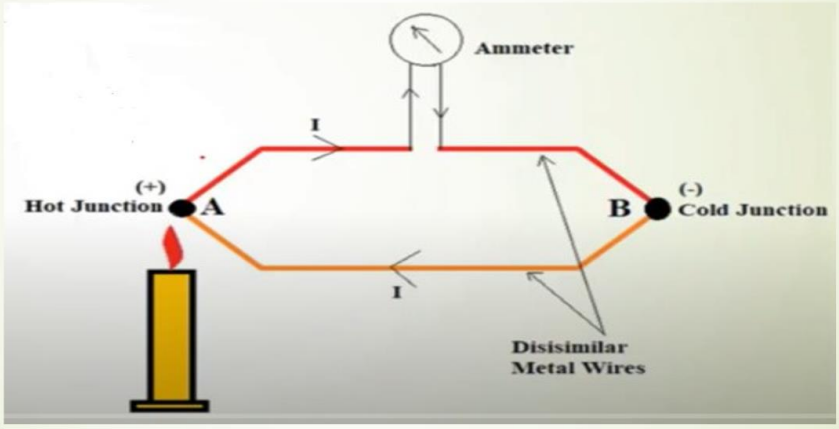
A type of **actinometer** used to measure **broadband solar irradiance** on a **planar surface.**

It is a sensor that is designed to measure the **solar radiation flux density** (in **watts per metre square**) from a **field of view of 180 degrees**.

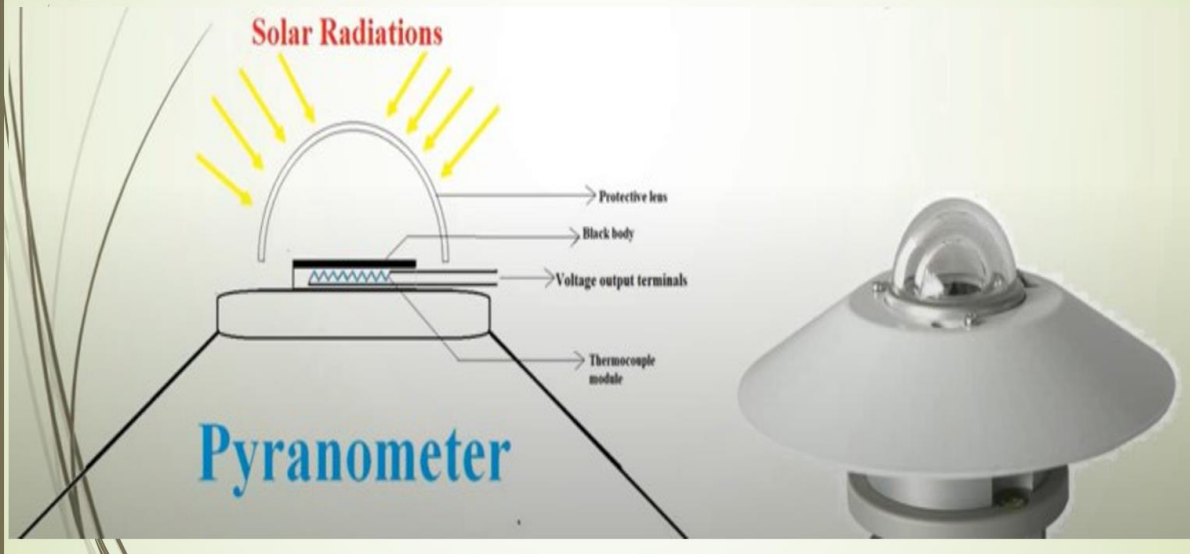
The name pyranometer has a **Greek origin**, "pyr" : "fire" and "ano" : "above, sky".

Instruments used to measure heating power of radiation, used in meteorology to measure solar radiation as pyrheliometers / pyranometers.

Thermo couple



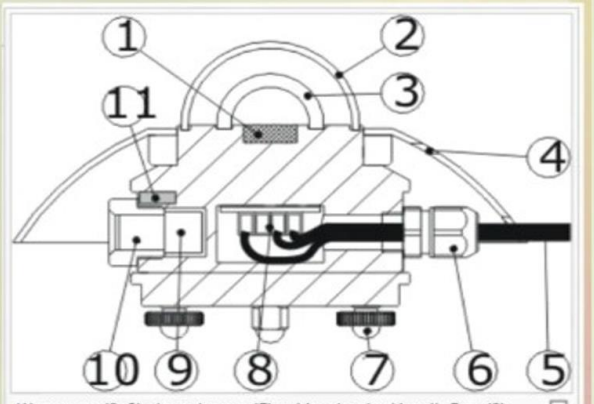
PYRANOMETER



PYRANOMETER (contd.)

MAIN COMPONENTS :

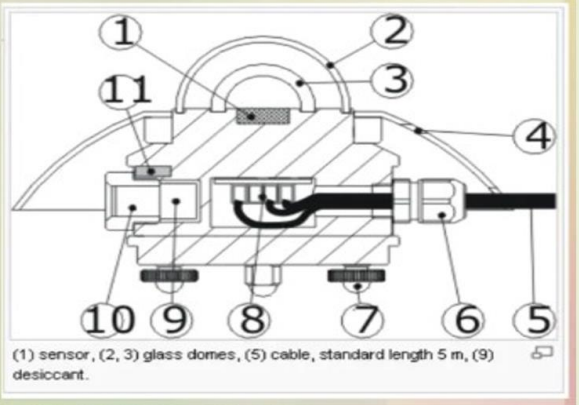
1. Thermopile Sensor with a Black Coating :
   1. absorbs all solar radiation,
   2. has a flat spectrum covering the 300 to 50,000 nanometer range,
   3. has a near-perfect cosine response.
2. Glass dome.
   1. limits the spectral response from 300 to 2,800 nanometers (cutting off the part above 2,800 nm), while preserving the 180 degrees field of view.
   2. shields the thermopile sensor from convection.



(1) sensor, (2, 3) glass domes, (5) cable, standard length 5 m, (9) desiccant.

PYRANOMETER (contd.)

3. Black coating on the thermopile sensor :
   1. absorbs solar radiation, which is converted to heat.
   2. The heat flows through the sensor to the pyranometer housing.
   3. The thermopile sensor generates a voltage output signal that is proportional to the solar radiation.



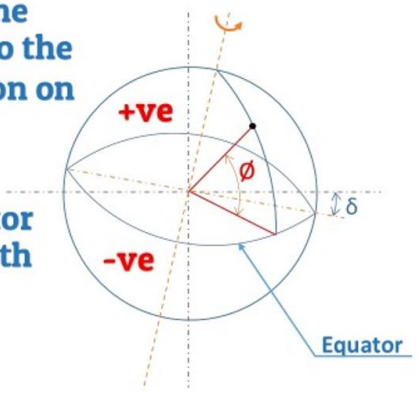
(1) sensor, (2, 3) glass domes, (5) cable, standard length 5 m, (9) desiccant.

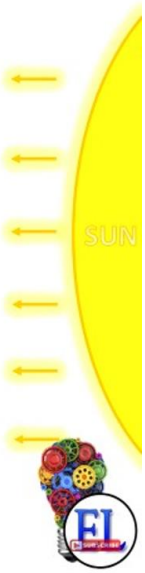
3b)

Angle of Latitude (Ø):

It is the vertical angle between the line joining that point of location to the centre of the earth and its projection on an equatorial plane.

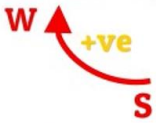
When the point is north of equator the angle is positive and when south it is negative.



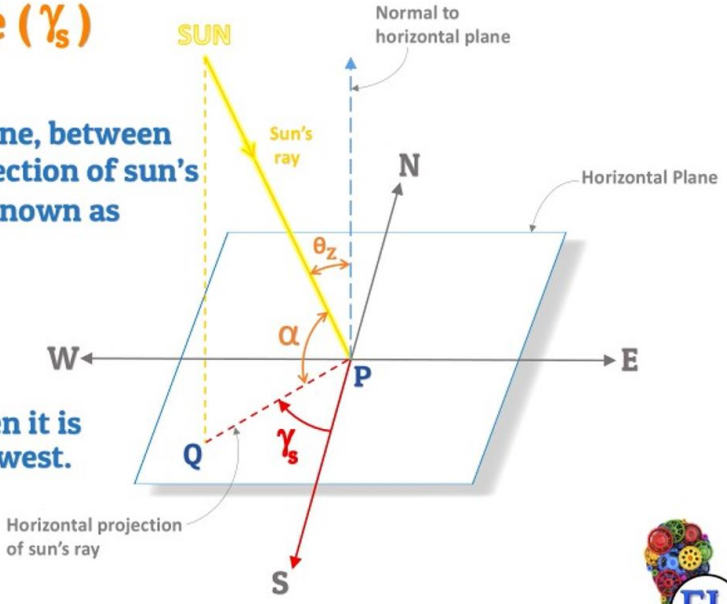


Solar azimuth angle (γ_s)

The angle on a horizontal plane, between the line due south and the projection of sun's ray on the horizontal plane is known as Solar azimuth angle (γ_s).



It is considered as positive when it is measured from south towards west.



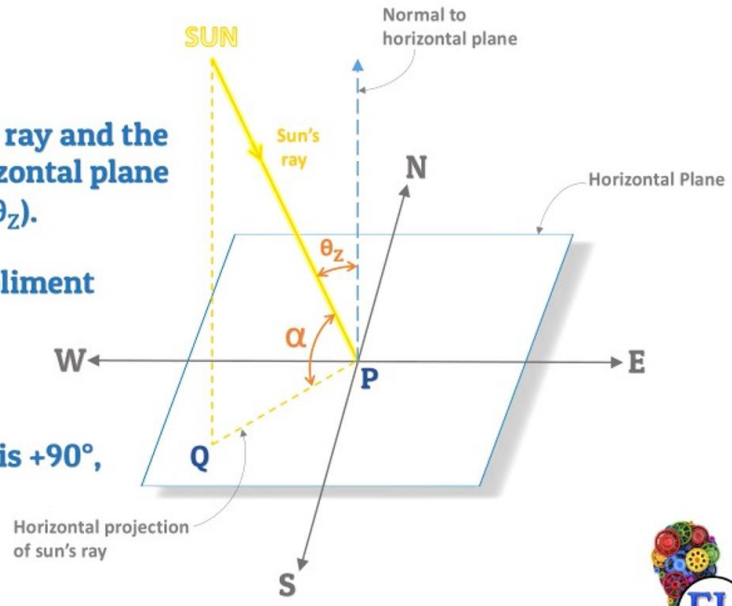
Zenith angle (θ_z)

The angle between the sun's ray and the perpendicular (normal) to horizontal plane is known as the Zenith angle (θ_z).

Also, Zenith angle is compliment of inclination (altitude) angle,

i.e. $\alpha + \theta_z = 90°$

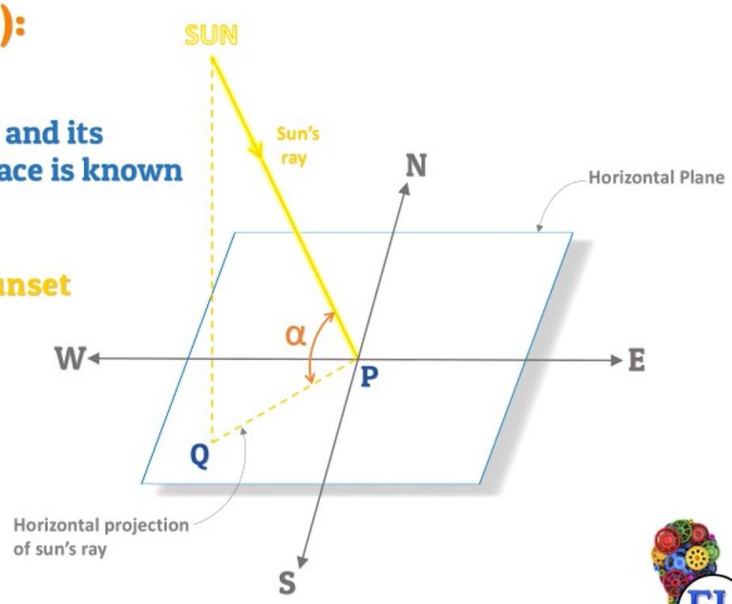
Hence, at sunrise zenith angle is +90°, whereas -90° at sunset.



Inclination angle (α):

The angle between sun's ray and its projection on a horizontal surface is known as the inclination angle (α).

→ $\alpha = 0°$ at sunrise and sunset



4a)

Solar Water Heater

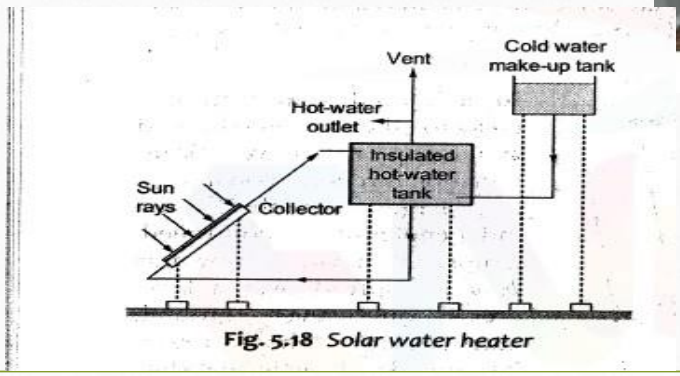


Fig. 5.18 Solar water heater

Solar cooker

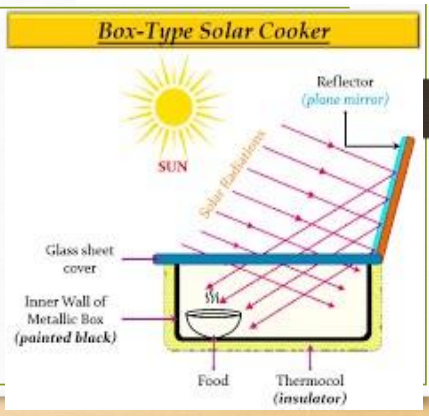
1. **Box type solar cooker**

Size: 60cm*60cm*20cm

Reflector mirror : provides direct radiation and reflected radiation

2 layer glass cover

Temperature: 140-160 degree Celsius



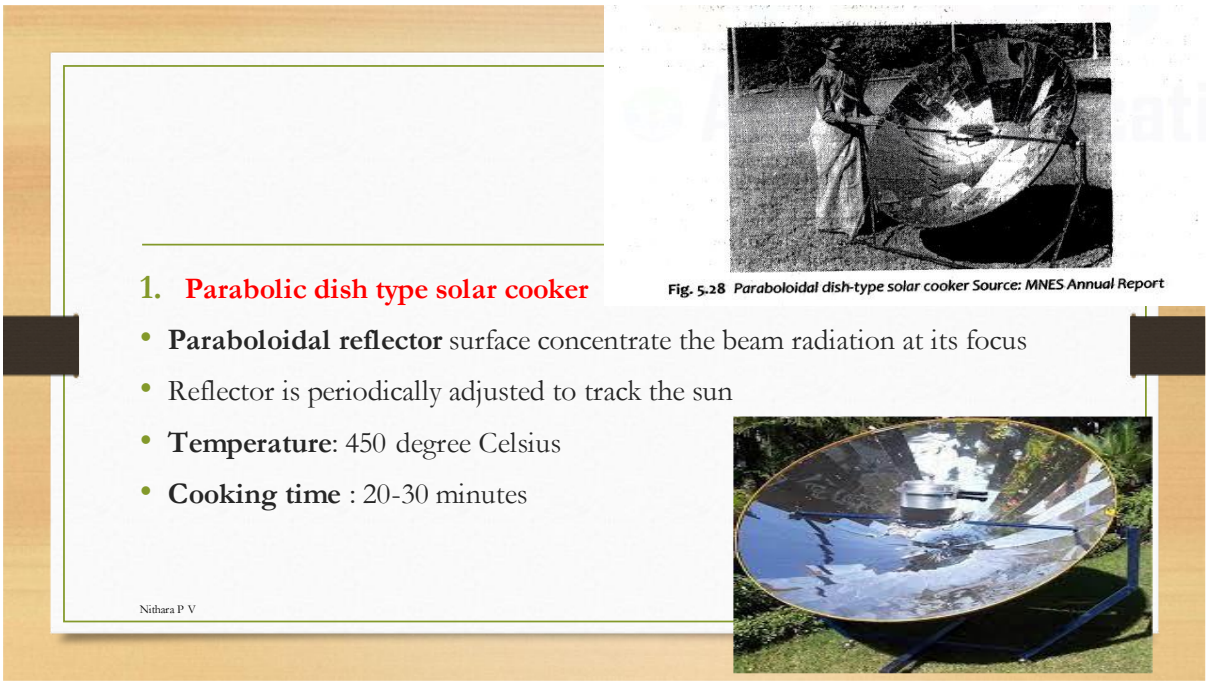


Fig. 5.28 *Paraboloidal dish-type solar cooker Source: MNES Annual Report*

4b.

Solar passive cooling through ventilation

- Utilizes a **solar chimney effect**
- Effective where **outside temperature are moderate**.
- Solar radiation allowed to heated up the air between glazing and interior south wall.
- Heated air rises up , is ducted outside and warm air from the room is drawn into this space due to natural draught.

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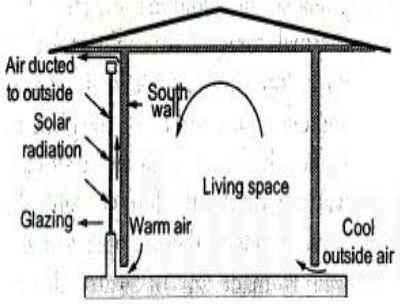


Fig. 5.21 Solar passive cooling through ventilation

Solar passive cooling through dehumidification

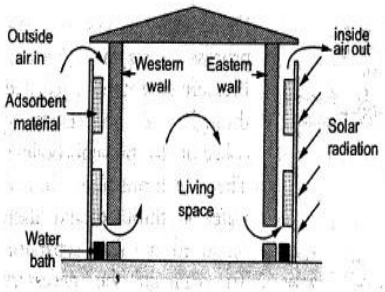


Fig. 5.22 Solar passive cooling through dehumidification

- In dehumidification system, moisture of the air in the room is reduced and cooling is maintained by **adsorption and evaporation.**

East and west facing wall of specially designed house are provided with **solid adsorbent material and water bath.**

- Air circulation maintained using **chimney effect.**

5a)

MAXIMIZING SOLAR PV OUTPUT AND LOAD MATCHING

- **To make the use solar PV system, output is maximized by,**
- 1.***Track the sun position***
- ***2. Electrically track the operating point(Maximize the load under different insolation and temperature)***
- ***Operating point is determined by intersection of source line and load Line.***
- ***Maximum power is available from the PV system for a load resistance of R2***

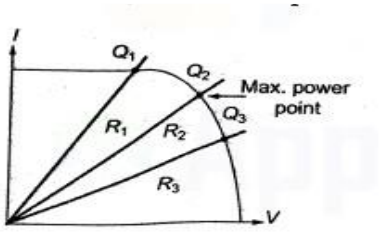


Fig. 6.22 *Load matching with resistive load*

5b)

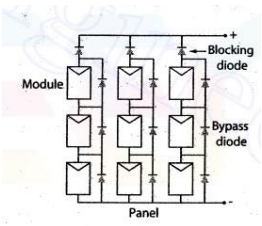
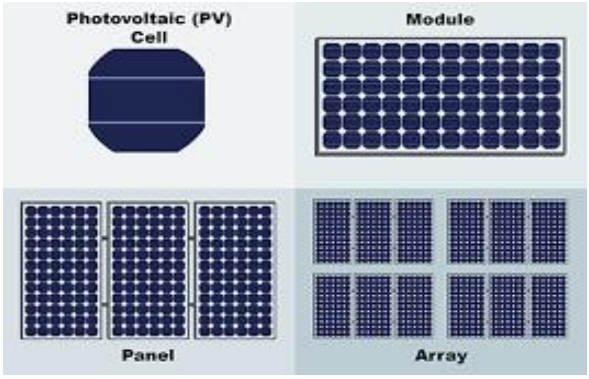


Fig. 6.21 *A typical panet series-parallel connection of modules*



5c)

MAXIMUM POWER POINT TRACKER(MPPT)

- I-V characteristics keeps on changing with insolation and temperature.
- In order to receive the maximum power, the load must adjust itself according to track the maximum power point.
- An ideal load is one that tracks

  Maximum power point.
- If operating point depart from MPPT ⟶

Interpose electronic maximum point tracker

- MPPT ~~DC~~ -DC switching voltage regulator

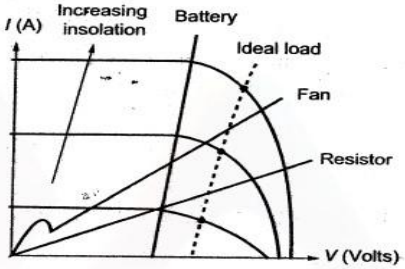


Fig. 6.23 *Characteristic fo PV and some loads*

- Output voltage of buck-boost converter is given by

$$V_{out} = \frac{D}{1-D} V_{in}$$

- Power output is given by PV system
- P=V*I
- Incremental current and voltage is mentioned

$$P + \Delta P = (I + \Delta I) . (V + \Delta V)$$

- After ignoring small terms

$$\Delta P = \Delta V . I + \Delta I . V$$

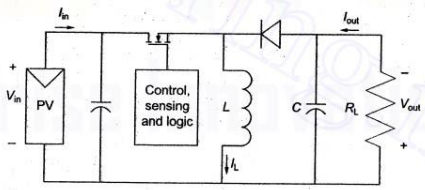


Fig. 6.24 *Maximum point tracker using buck-boost converter*

- ΔP must be zero for maximum point $\frac{dV}{dI} = -\frac{V}{I}$

It may be noted here that $\frac{dV}{dI}$ is the dynamic impedance of the source, which is required to be equal to negative of static impedance, $\frac{V}{I}$.

- ***3 possible for strategy of operation of MPPT:***
- **1)By monitoring the dynamic and static impedance(Zd=-Zs)**
- **2)By monitoring power output**

  Maximum power point atdP/dV=0

  dP/dV=+Ve: operating voltage increased.

  dP/dV=-Ve: Operating voltage is decreased.
- **3)By fixing output voltage as a fraction ofVoc**

Most PV cell , Voltage at maximum power point= Constan

Open circuit voltage

Operating voltage: K *Voc

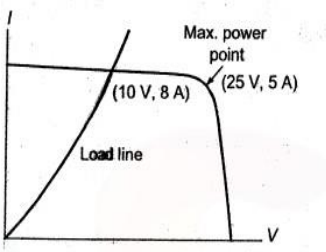


Fig. 6.25 PV system – load characteristics

6a)

SOLAR CELL FUNDAMENTALS

- **ELECTRIC CURRENT CONDUCTION IN SEMICONDUCTOR**
- Semiconductors(Si&Ge) have 4 valance electrons.
- Silicon atoms combine to form a solid they arrange themselves into an orderly pattern called a crystal.
- Each valance electron belongs to 2 neighbouring atoms and attracted by them with equal and opposite force: Covalent bond.
- At zero temperature: Semiconductor is perfect insulator
- Temperature increased: Dislodged electron is free electron, so breaking the covalent bond, free electron-hole pair is produced.
- Room temperature: Less electron-hole pair
- Merging of free electron and hole is known as recombination

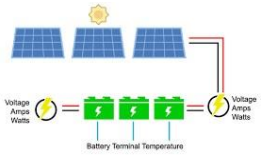
6b)

BALANCE SYSTEM (BOS) COMPONENTS

- BOS: Batteries, Charges, Charge controller, MPPT, Inverter, Mounting material for the module, wire and wiring components, lighting protector, grounding connection, battery fuses, battery cable and battery container
- BOS components are regulated by codes or standards

1. Batteries

Commonly used batteries: Lead acid battery, Nickle cadmium battery and lithium ion storage battery



General parameters of batteries are

a)Battery Voltage

3 types of voltage available across the terminal

a) Open circuit voltage

b)Nominal voltage

c) Cut off voltage

Rechargeable battery are available: 3V,6V,12V,24V

- **Battery Capacity**
  - It is maximum charge storage capacity of a battery expressed in Ah.
- **Battery life cycle**
  - It is defined as number of complete charge /discharge cycles that a battery can perform before its storage capacity falls below 80% of its rated capacity.
- **State of charge(SOC)**
  - Amount of charge available with the battery at that instant.
- **Depth of discharge**
  - Energy withdrawn from the battery expressed as percentage of its full capacity.
- **Discharge rate or C -rating**
  - Charge or discharge current given in terms of capacity of battery divided by number of hours for full charge or discharge
- **Self discharge**
  - Loss of stored charge when the battery is not in use

- **Deep discharge battery**
  - Ordinary battery wont allow to discharge beyond 50% DoD. Batteries allowed to discharging up to 80% or more.
- **Battery temperature during discharge**
  - Low temperature: battery capacity and battery voltage will reduce
  - High temperature: capacity will reduce due to deterioration in chemical reaction.
  - Temperature range: 20 -40%
- **Battery charging**
  - Different battery: Different method of charging
  - Lead acid battery : 3 stages

1. Constant current charge
2. Topping charge
3. Float charge

7a)

Considerations & guidelines

Factors to be considered

1. Hill effect

2. Roughness or amount of earth's friction on wind

3. Tunnel effect

4. Turbulence

5. Variations in **wind speed**: influence of **sun**

6. Wake: 3 rotor diameter away

7. Wind **obstacles**

8. Wind **shear**: difference in wind speed(tips)

Guidelines

1. Height and costal sites
2. ✖ Town and highly populated area
3. ✖ roof mounted turbines
4. Distance of caballing
5. Turbine height is twice obstacle distance
6. Speed of wind
7. Remote location issues

5b)

Energy availability in wind

- Power equation $P = \frac{1}{2}(\rho S V^3)$
- Speed of wind (V)

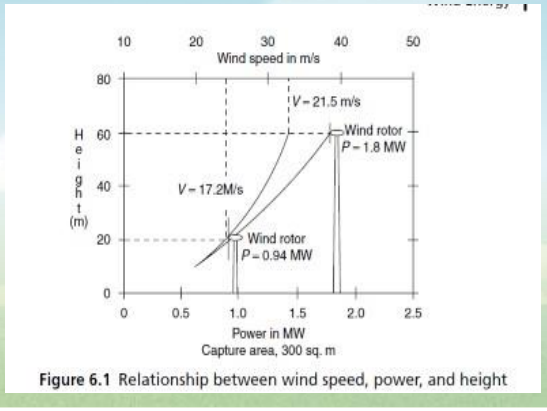


Figure 6.1 Relationship between wind speed, power, and height

9a)

CLASSIFICATION OF WECS

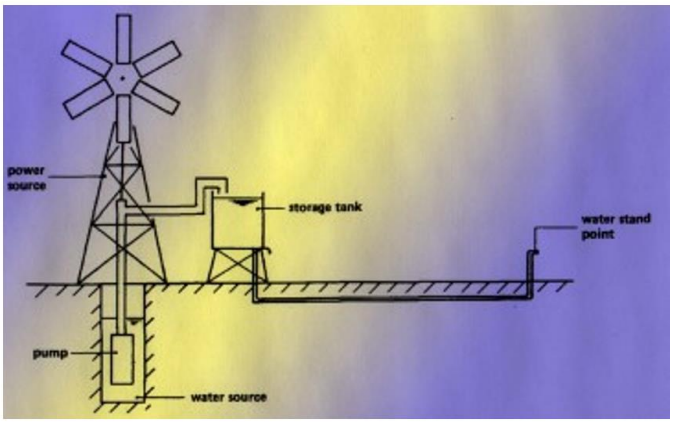
- **Broad Classifications**
  - Horizontal Axis Wind Turbines (HAWT)
  - Vertical Axis Wind Turbines (VAWT)
- **According to Size**
  - Small size machine (up to 2 kW) – used in farm, remote applications and places requiring low power
  - Medium size machine (2 kW to 100 kW) – residential or local use
  - Large size machine (100 kW and above) – used to generate power for distribution in central power grids. Two subclasses – (a) Single generator at single site (b) Multiple generators sited at several places over an area
- **According to Output Power**
  - DC Output – (a) DC generator (b) Alternator Rectifier
  - AC Output – (a) Variable frequency, variable or constant voltage AC (b) Constant frequency, variable or constant voltage AC
- **According to Rotational Speed of Aeroturbines**
  - Constant speed with variable pitch blades – uses synchronous generator with constant frequency output
  - Nearly constant speed with fixed pitch blades – uses induction generator
  - Variable speed with fixed pitch blades – uses constant frequency output system such as Field Modulated System, AC-DC-AC Link, Double Output Induction Generator, AC Commutator generator set etc.
- **According to Utilization of Output**
  - Battery storage
  - Direct connection to an electromagnetic energy converter
  - Other forms such as thermal potential etc. of storage
  - Interconnection with conventional electric utility grids

9b)

APPLICATIONS

APPLICATIONS REQUIRING MECHANICAL POWER

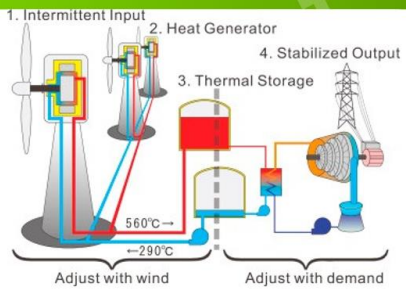
- **WIND PUMPS**: Simple and reliable reciprocating or centrifugal pumps (Wind Pumps i.e., low power turbines) are used to pump water to supply for feeding livestock, small scale irrigation, low head pumping for aquatic breeding, domestic water supply and to operate farm appliances



APPLICATIONS

- **HEATING**: producing heat with 100% efficiency using paddlewheel or other turbulent fluid systems by direct dissipation of mechanical power. Available hot water is used directly or for space heating

- **SEA TRANSPORT**: The wind energy is used to propel the sailboats in river and seas to transport men and materials from one place to another



AS OFF-GRID ELECTRICAL POWER SOURCE

- Generating electrical energy from machines of low rating (3 m rotor dia and 40 to 1000 W rating) for space heating, cooling of homes, water heating, battery charging, operating domestic appliances such as fan, light and small tools

- Turbines of 50 kW rating are used to generate electricity for navigation signal such as lighthouse, remote communication, weather stations and offshore oil drilling platforms

- Aero-generators (100 to 250 kW) acting as stand-alone or connected with mini-grid supply power to isolated populations, farm cooperatives, commercial refrigeration, desalination or other small industries

- Aero-generator are installed at top of the hill to generate electricity to the pump situated at lower level for pumping water. Uses the same pumped storage to store energy and utilize it during no wind periods

10a)

ADVANTGES

- × Renewable source of energy
- × Environmental friendly system
- × Avoid fuel provision and transport
- × Small scale system is less costlier
- × Large scale system is costlier but lower costs can be achieved by mass production

DISADVANTGES

- × Wind energy is available in dilute form
- × Wind is fluctuating in nature
- × Due to irregular winds they require storage system
- × Noisy operation
- × High overall weight (110 kg for a larger system)
- × Large area required as a propeller with 1 m to 3 m diameter delivers power in 30 W to 300 W range
- × Difficult to maintain

10b)

TYPES OF WIND MACHINES

Horizontal axis type (wind axis rotors)

- Oriented normal to direction of wind
- Single bladed, multibladed and by-cycle multibladed

Vertical axis type (cross wind axis rotors)

- Effective surface of rotor moves in the same direction as the wind
- Savonious or S type rotor (low velocity wind) and Darrieus type rotor (high velocity wind)