UNIT - II

Problems on Solar Energy

The global formula to estimate the electricity generated in output of a photovoltaic system is: **$E = A * r * H * PR$**

E = Energy (kWh)

A = Total solar panel Area (m^2)

r = Solar panel yield (%) = Electrical power (in kWp) of one solar panel divided by the Area of one panel

H = Annual average solar radiation on tilted panels (200 kWh/m^2 to 2600 kWh/m^2.)

PR = Performance ratio, coefficient for losses (range between 0.5 and 0.9, default value = 0.75)

The unit of the nominal power of the photovoltaic panel is called "Watt-peak" (Wp or kWp = 1000 Wp or MWp=1000000 Wp).

Problem 1: Calculate the solar energy output of a photovoltaic system per year and day for the following data:

i) Electric power of one solar panel: 250 Wp

ii) Area of one panel: 1.6 m^2

iii) No. of panel: 1

iv) Annual average solar radiation on tilted panel: 2000 kWh/m^2.

v) Performance ratio: 0.75

Solution:

A = Total solar panel Area = 1.6 m^2

H = Annual average solar radiation on tilted panels = 2000 kWh/m^2.

PR = Performance ratio = 0.75

r = Solar panel yield (%) = Electrical power (in kWp) of one solar panel/ Area of one panel

Electrical power of one solar panel = 250 Wp = (250/1000) = 0.25 kWp

r = (0.25/1.6)x100 = 15.6 %

E = A x r x H x PR = 1.6 x 15.6 x 2000 x 0.75 = 37440 kwh/year

Per day = 37440/365 = 102.57 kwh/day

(**Note:** As the No. of panels increases Total solar panel Area increases.)

Problem 2: Calculate the solar energy output of a photo voltaic system for the following data:

i) Electric power of one solar panel: 280 Wp

ii) Area of one panel: 1.8 m^2

iii) No. of panel: 1

iv) Annual average solar radiation on tilted panel: 2080 kWh/m^2.

v) Performance ratio: 0.80

Solution:

A = Total solar panel Area = 1.8 m^2

H = Annual average solar radiation on tilted panels = 2080 kWh/m^2.

PR = Performance ratio = 0.80

r = Solar panel yield (%) = Electrical power (in kWp) of one solar panel/ Area of one panel

Electrical power of one solar panel = 280 Wp = (280/1000) = 0.28 kWp

r = (0.28/1.8)x100 = 15.5 %

E = A x r x H x PR = 1.8 x 15.5 x 2080 x 0.8 = 46425.6 kWh

Problems on Wind Energy:

Calculation of Wind Power hitting wind turbine

Wind is made up of moving air molecules which have mass - though not a lot. Any moving object with mass carries **kinetic energy** in an amount which is given by the equation:

$$\textbf{Kinetic Energy} = \textbf{0.5 x Mass x Velocity}^2$$

Where the mass is measured in **kg**, the velocity in **m/s**, and the energy is given in **joules**.

Air has a known density (around 1.23 kg/m^3 at sea level), so the mass of air hitting our wind turbine (which sweeps a known area) each second is given by the following equation:

Mass/sec (kg/s) = Velocity (m/s) x Area (m^2) x Density (kg/m^3)

And therefore, the **power** (i.e. energy per second) in the wind hitting a **wind turbine** with a certain swept area is given by simply inserting the *mass per second* calculation into the standard kinetic energy equation given above resulting in the following **vital** equation:

Power = 0.5 x Swept Area x Air Density x Velocity^3

Where **Power** is given in Watts (i.e. joules/second), the **Swept area** in m^2,the **Air density** in kg/m^3, and the **Velocity** in m/s.

Swept area $A = \pi r^2$, where r is radius or length of the blade

$A = (\pi d^2/4)$, where d is diameter of the blade

Problem 3: Calculate the wind power hitting the wind turbine with a rotor blade diameter of 126 m. Air density is 1.23 kg/m^3 and Air velocity is 14m/s.

Solution:

Swept area $A = (\pi d^2/4) = (\pi\ 126^2/4) = 12470\ m^2$

Wind Power = 0.5 x Swept Area x Air Density x Velocity^3

Wind Power = 0.5 x 12,470 x 1.23 x $(14)^3$

= 21,000,000 Watts

= 21MW

Problem 4: Calculate the size of wind mill to meet the annual energy requirement of an industry with the following data:

i) Annual energy requirement of industry = 20,000 kwh

ii) Annual average wind velocity = 18 km/hr.

iii) Coefficient of performance of turbine = 0.4

iv) Efficiency of rotor = 0.9

v) Efficiency of generator = 0.9

vi) Assume density of air = 1.0 kg/m^3

Solution:

Velocity = (18x1000)/3600 = 5m/s

Consider one unit area of turbine

Wind power = 0.5 x Swept Area x Air Density x Velocity^3

= 0.5 x 1 x 1 x 5^3 = 62.5 Watts

Wind power that is converted in to useful power = 0.4 x 0.9 x 0.9 x 62.5

= 20.25Watts

Power consumption is expressed in wh or kwh = (20.25 x 1h) = 20.25wh

Annual power density produced by turbine per unit area

= Power density x no. of hours in the year

= 20.25 x365 x 24

= 177390 wh/m^2 /year

= 177.39 kwh/m^2 /year

Total energy required per year = 20,000 kwh

Energy of turbine per unit area =177.39 kwh/m^2

Area of turbine required, A = 20,000/177.39 = 112.75m^2

$(\pi \times D^2)/4 = 112.75$

$D = \sqrt{\frac{112.75 \times 4}{\pi}}$ **= 11.98m =12m or Radius , R =6m**

Problem 5: The annual power requirement of an industry is 30,000 kwh. The management has decided to meet this energy requirement through wind energy. Calculate the size (diameter) of wind mill to meet the annual energy requirement. The following data:

i) Annual average wind velocity at the site = 20 km/hr.

ii) Coefficient of performance of turbine = 0.4

iii) Coefficient of transmission = 0.85

iv) Coefficient of generator = 0.89

v) Density of air = 1.0 kg/m^3

Solution:

Velocity = (20x1000)/3600 = 5.55m/s

Consider 1 m^2 area of turbine

Wind power = 0.5 x Swept Area x Air Density x $Velocity^3$

$= 0.5 \times 1 \times 1 \times 5.55^3 = 85.5$ Watts

Wind power that is converted into ~~turbine~~ useful power = 0.4 x 0.85 x 0.89 x 85.5

= 25.87Watts

Power consumption expressed in wh or kwh = (25.87 x 1h) = 25.87wh

Annual power density produced by turbine per unit area

= Power density x no. of hours in the year

= 25.87 x 365 x 24

= 226621wh/m^2 /year

= 226.621 kwh/m^2 /year

Total energy required per year = 30,000 kwh

Energy of turbine per unit area =226.621 kwh/m^2

Area of turbine required, A = 30,000/226.621 = 132.38m^2

$(\pi \times D^2)/4 = 132.38$

$D = \sqrt{\frac{132.38 \times 4}{\pi}}$ = **12.98m =13m or Radius , R = ~~6m~~** 6.5m