MODULE-3: SOLAR ENERGY

Structure

3.1 Introduction :

Through out the world, the energyconsumption has been growing withadvancecivilization. Today, energy consumption is directl y related to the standard of living of thepeople of nationanddegree of Industrialization of the country. The existing energy sources of fossil fuels may. not~ Iadequate to meet the ever increasing energy demands. These energy resources are also depletingin nature and may be exhausted in a short time. Thus.a necessary exists to look for otherformof energy sources i.e., non-conventional energy sources such as geothermal, ocean tides,wind,solar, etc. Among all these energy sources, solar energy is the most promising alternativeener~source which will meet considerable part of energy demand. The solar energy has itsOwnadvantages such as its availability at free of cost, inexhaustible, free from polution, availablem'\almost all parts of the world, and is available in abundence. Solar water heaters, spaeeheaters,solar cookers, solar photo-voltaic cells, solar refrigerators and solar thermal power plantsare

used for various purposes and in all these devices, solar energy is used either for the purposeof waterheating,spaceheatingor cooling or forconversionto otherformofenergy.Theenergycomes from the sun, keeps the temperature of the earth higher, causes current in the atmosphereand ocean. The differential heating of the earth's surface by the sun produces the wind andenergy of the wind may be used to run wind mills which in turn drives a generator to produce

electricity.Solar energy is a renewable resource and cannot be depleted. It has the greatest potentialof all renewable energy sources. The sun constantly delivers 1.36 kW (1360 joules/see) ofenergy per square meter to the earth. It is one of the promising alternative energy source anditsnature and magnitude available on earth's surface varies depending on the location and weatherconditions.

The earth's surface receives 106watts of solar power which is 1000times more thantheactualpower needed through out the world.The 5 percentutilizationof solarenergy willbe 50imeswhatthe worldwillrequire.

Theapplications of solar energy are:

i. Spaceheatingor coolingfor residentialbuilding.

ii. Solarwaterheating

iii. Solarcookers

iv. Solardistillationon a smallscale

v. Dryingof agriculturaland animalproductsby suitablesolar driers.

vi. Foodrefrigeration

vii. Electricpowergeneration

viii. Solar ponds

ix. Directconversionof solarenergyintoelectricityby usingphoto-voltaiccells

x. Bio-conversionand windenergy,whichare indirectsourceof solarenergy

Solar radiation outside the earth's atmosphere

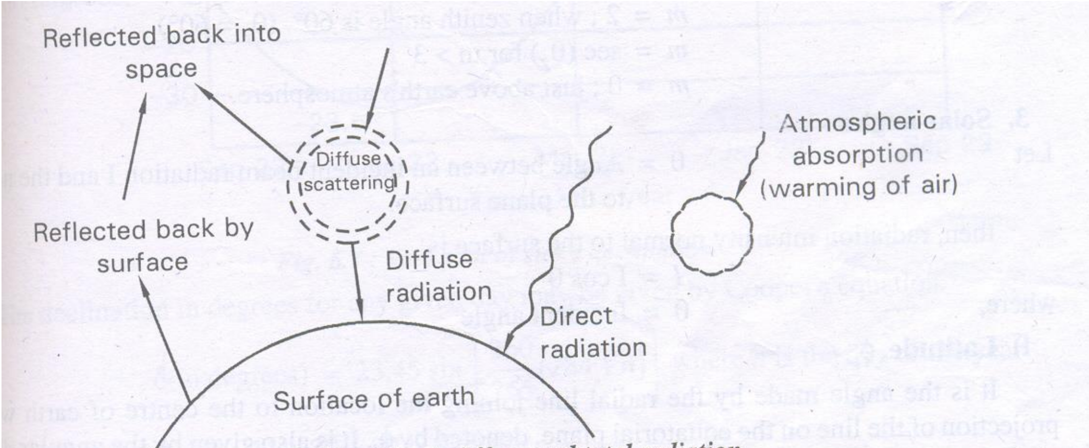

Fig. 6.5 : Direct, diffuse and total radiation

Thesunisconsideredas alargesphereofdiameter1.39x 106km,consistingofveryhotgases. Theearth's diameteris 1.27x 104km andthe averagedistancebetweentheearthandsun is1.496x 108km.The earth receives beamradiationfrom the sun, almost parellel,becauseofverylargedistancebetweenthesunandtheearth.Eventhoughsun'sbrightnessvariesfromcentreto its edge, we assume that the brightness is uniform all over the solar disc. It is to be notedthatthe radiationcoming from the sun is almostequal to that of radiationcomingfrom a Blacksurfacewhich is at 5762 K.Theenergy flux radiated from the sun outside the earth's atmosphere is consideredto beconstantandthis yieldsthe definitionof solar constant.Solar constant is the rate at whichsolarenergyreaches at the top of the atmosphereand is denotedby Isc.This is the amountof energyreceivedfrom the sun in unit time on a unit areaperpendicular to the sun's directionand at theMeandistance of the earth from the sun.The distance between the earth and the sun varies asearthrevolvesaroundthe sun in an ellipticalorbitwitha smalleccentricityandsunatoneof thefoci.Thischangesthesolarradiationandhence then ergyflux reachingtheearth's atmosphere.

Thusthe solarconstant value obtained is the average one and a standard value of 1353W/m2
was adopted in 1971. Later, the solar constant value was revised to 1367 W/m2,throughmeasurements.The variationin the extra terrestrialflux, outsidethe earth's atmospheredueto change indistance between earth and the sun produces a sinusoidal variation in the intensity of solarradiation thatreachestheearth.Thevalueof thisextraterrestrialfluxon anydayof theyearcanbe obtainedby using the equation

The figure 6.1 showsthe spectral distributionof extra terrestrial solar radiation.It is seenfrom the figure that the spectral beam radiation first increases shortly with wave lengthandreachesa maximum value of 2074 W/m2 at 0.48 Ilm wave length and then decreases. It is to benotedthat,upto a wave lengthof 4 Ilm,99 percent of sun's radiationis obtained.

3.2 Solar radiation at the Earth's surface

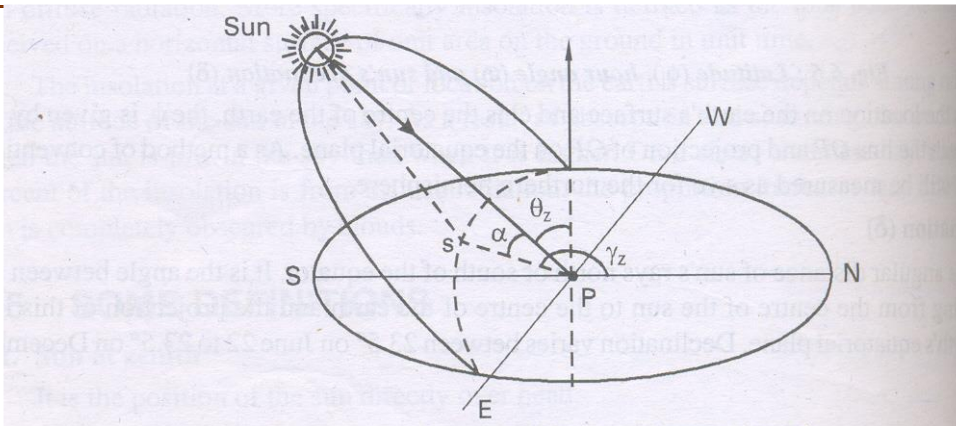

Fig. 6.8 : Sun's zenith, altitude and azimuth angles

The solarenergyreceivedatthe earth's surfacedependsonthetime of day,thetimeofyear, Locallatitudeandamountofcloudcover,amountof atmosphericpollutionetc.Thesolarradiation Receivedat theearth's surfaceisin attenuatedformandiscomposedofbeamanddiffuseradiation, Scatteredcomponentandthereflectedshortwavelengthradiationfromthe surroundingterrestrial surfacesafter subjectedto themechanismsof absorptionandscatteringduring its travelthroughthe earth's atmosphere. The ozone, water vapour and to some extent other gases (like CO2,N02, CO, °2 and CH4)and particulate matter, absorb all the ultraviolet solar radiation andenergy in the infraredrange.This absorptionof solarradiationby the atmosphereincreasesitspresenceof allgaseous molecules andparticulatematter or dust particlesin the atmosphere, scatters the solarradiationi.e.,changesitsdirection.The scatteredradiationisredistributedin allthe directions,aportion of whichgoes back in to the space and remainingreaches the earth's surface as diffuseradiation.Thustheradiationfinallyreach theearth'ssurfaceconsistspartlyofbeamradiationandItis obvious that the solar radiation recei ved at earth's surface is maximum when theatmospheiresnotcoveredorpartlycoveredwithcloud.However,themechanismsof absorptionandscatteringare similar under the conditions of cloudless sky or atmosphere with clouds.Solaradiation which is not scattered or absorbed and reaches the earth's surface directlyfromthesun without changing its direction is called "Beam or Direct radiation". The solar radiationreceivedat the earth's surface after scattering absorption and reflection by the atmosphere iscalled"DIffuseradiation". It is the radiation at the earth's surface from all parts of the sky'shemispheraend its direction has been changed by scattering, absorption and reflection. Thereforethetotalradiation received at the earth's surface is the sum of beam and diffuse radiation and isknownastotalor globalradiation.Reflected radiation

The intensity of diffuse radiation is not isotropic in nature, but it changes with respect tolatitudetime of the year, time of the day, content in the atmosphere and many other factors.

A term called air mass (AM}is often used to indicate the distance travelled by beam radiationthrough the atmosphere to reach a location on the surface of the earth. The air mass (AM) is thetermrepresents the ratio of atmospheric mass through which beam radiation passes to the massof the atmosphere, ifthe position of the sun is directly overhead (i.e., at its zenith).

3.3 Solar Radiation Measurement

It isnecessarytomeasuresolarradiationbecauseofuseof solarheatingandcoolingdevicesand the results of the measurements are used to predict the performance of the devices. Theinstrument used for measurement of solar radiation includesmeasurementof directsolarradiationanddiffuse solar adiationor totalsolarradiation.Theinstrumentsusedformeasurementofsolarradiationincludesmeasurementof direct solarradiationanddiffusesolarradiationor totalsolarradiation.Theinstrumentswhichare commonly used formeasuringthesolarradiationare

1.*Pyrheliometer:*Aninstrumentwhichmeasuresbeam radiationintensityasafunctionof incidentangle,and

2. *Pyranometer:* Aninstrumentused to measuretotal solarradiation.

3.4Pyrheliometers

This instrumentis used to measurebeamradiationand operatesonthenopileeffect.Theinstrument consists of a tube whose axis is aligned with the direction of sun's rays by usingtwo axis tracking mechanism and alignment indicator. The tube contains a sensor disc at itsbasenmthe arrangement is made such that the diffuse radiation is blocked from the sensor surlaceandhence the device measures only Beam radiation. The use of shading ring also gives measurementof direct solar radiation, the value of which is obtained by subtracting the shaded (diffuse) readingfromthe unshaded(global)reading. .

Thepyrheliometerswhicharecommonlyused are

i) Angstromcompensationpyrheliometer

ii) Abbot silverdiskpyrheliometerand

iii) Eppleypyrheliometer

Questions

1. Explain briefly the application of Solar pond
2. Draw the sketch and label the parts (i) Horizontal wind mill (ii) Vertical wind mill
3. Define terms: (i) solar radiation (ii) diffused radiation (iii) Direct radiation and (iv)Extra terrestrial radiation.
4. Classify solar radiation measuring instruments. Explain any one instrument with Sketch
5. With the help of a neat sketch describe the photovoltaic cell
6. With a neat sketch explain the flat plate solar collector.
7. List the problem associated woth solar power