UNIT-I

PRINCIPLES OF SOLAR RADIATION

Role and potential of new and renewable source

India has a vast supply of renewable energy resources, and it has one of the largest programs in the world for deploying renewable energy products and systems. Indeed, it is the only country in the world to have an exclusive ministry for renewable energy development, the Ministry of Non-Conventional Energy Sources (MNES). Since its formation, the Ministry has launched one of the world's largest and most ambitious programs on renewable energy. Based on various promotional efforts put in place by MNES, significant progress is being made in power generation from renewable energy sources. In October, MNES was renamed the Ministry of New and Renewable Energy.

Specifically, 3,700 MW are currently powered by renewable energy sources (3.5 percent of total installed capacity). This is projected to be 10,000 MW from renewable energy by 2012.

The key drivers for renewable energy are the following:

- o The demand-supply gap, especially as population increases
- o A large untapped potential
- o Concern for the environment
- o The need to strengthen India's energy security
- o Pressure on high-emission industry sectors from their shareholders
- o A viable solution for rural electrification

Also, with a commitment to rural electrification, the Ministry of Power has accelerated the Rural Electrification Program with a target of 100,000 villages by 2012.

Introduction In recent years, India has emerged as one of the leading destinations for investors fromdeveloped countries. This attraction is partially due to the lower cost of manpower and good quality production. The expansion of investments has brought benefits of employment, development, and growth in the quality of life, but only to the major cities. This sector only represents a small portion of the total population. The remaining population still lives in very poor conditions.

India is now the eleventh largest economy in the world, fourth in terms of purchasing power. It is poised to make tremendous economic strides over the next ten years, with significant development already in the planning stages. This report gives an overview of the renewable energies market in India. We look at the current status of renewable markets in India, the energy needs of the country, forecasts of consumption and production, and we assess whether India can power its growth and its society with renewable resources.

The Ministry of Power has set an agenda of providing Power to All by 2012. It seeks to achieve this objective through a comprehensive and holistic approach to power sector development envisaging a six level intervention strategy at the National, State, SEB, Distribution, Feeder and Consumer levels.

Environmental impacts of solar energy:

Every energy generation and transmission method affects the environment. As it is obvious conventionalgenerating options can damage air, climate, water, land and wildlife, landscape, as well as raise the levels of harmful radiation. Renewable technologies are substantially safer offering a solution to many environmental and social problems associated with fossil and nuclear fuels (EC,1995,1997). Solar energy technologies (SETs) provide obvious environmental advantages in comparison to the conventional energy sources, thus contributing to the sustainable development of human activities
Not counting the depletion of the exhausted natural resources, their main advantage is related to the reduced CO_2 emissions, and, normally, absence of any air emissions or waste products during their operation. Concerning the environment, the use of SETs has additional positive implications such as:

* reduction of the emissions of the greenhouse gases (mainly CO_2,NO_x) and prevention of toxic Gas emissions (SO_2,particulates)
* reclamation of degraded land;
* reduction of the required transmission lines of the electricity grids; and
* improvement of the quality of water resources

The basic research in solar energy is being carried in universities and educational and researchinstitutions, public sector institution, BHEL and Central Electronic Limited and carrying out a coordinated program of research of solar energy.

The application of solar energy is

1. Heating and cooling residential buildings
2. Solar water heating
3. Solar drying of agricultural and chemical products.
4. Solar distillation of a small community scale
5. Salt production by evaporation of sea water
6. Solar cookers
7. Solar engines for water pumping
8. Food refrigeration
9. Bio conversion and wind energy and which are indirect source of solar energy
10. Solar furnaces
11. Solar electric power generation by
    i) Solar ponds
    ii) Steam generators heated by rotating reflectors
    iii) reflectors with lenses and pipes for fluid circulation
12. solar photovoltaic cells which can be used for conversion of solar energy directly into electricity (or) for water pumping in rural agriculture purposes.

PRESENT SENERIO:

TPP	-	65.34%
HYDRO	-	21.53%

NUCLEAR	-	2.7%
RENEWABLE	-	10.42%
WIND CAPACITY	-	14550 MW.

20,000 MW solar by 2022.
Installed power generation capacity of India 181.558 GW
Per capita energy consumption stood at 704 KW.
1/3 GW of installed capacity by 2017

Solar Radiation

Solar energy, received in the form of radiation, can be converted directly or indirectly in to other forms of energy, such as heat and electricity. The major draw backs of the extensive application of solar energy of

1. the intermittent and variable manner in which it arrives at the earth's surface and
2. the large area require to collect the energy at a useful rate.

Energy is radiated by the sun as electromagnetic waves of which 99% have wave lengths in the range of 0.2 to 4.0 micro meter (1 micro meter = 10^{-6} meter)

Solar energy reaching the top of the earth's atmosphere consists of about

- 8% ultra violet radiation [short wave length >0.39 micrometer]
- 46% visible light [0.39 to 0.78 micrometer]
- 46 % infrared [0.78 micro meter above]

Solar constant

The sun is a large sphere of very hot gases, the heat being generated by various kinds of fusion reactions.Its diameter is 1.39 X 10^6 km while that of earth is 1.27 X 10^4 km. the mean distance between the two is 1.5 X 10^8 km. although the sun is large, its subtends angle of only 32 min. at the earth's surface.

The brightness of the sun varies from its center to its edge. However the calculation purpose the brightness all over the solar disc is uniform.

The total radiation from the sun is 5762 degrees K

The rate at which solar energy arise at the top of the atmosphere is called the solar constant I_{sc} . This is the amount of energy received in unit time on a unit area perpendicular to the sun's direction at the mean distance of the earth from the sun.

The solar constant value varies up to 3 % throughout the year, because the distance between the sun and the earth varies little throughout the year.

The earth is close set of the sun during the summer and farthest during the winter.

This variation in distance produces sinusoidal variation in the intensity of solar radiation I that reaches the earth.

I_{SC} = 1367 watts/m^2

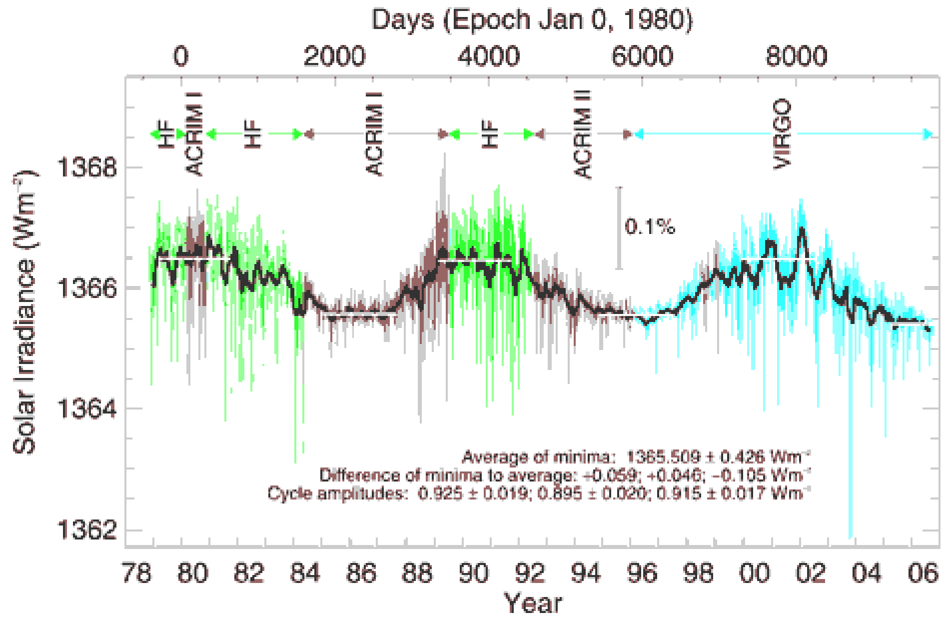
$\frac{I}{I_{SC}} = 1 + 0.033 \cos\frac{360\,n}{365}$. where n is the day of the year.

Spectral distribution of solar radiation intensity at the outer limit of the atmosphere

The luminosity of the Sun is about 3.86 x 1026 watts. This is the total power radiated out into space by the Sun. Most of this radiation is in the visible and infrared part of the electromagnetic spectrum, with less than 1 % emitted in the radio, UV and X-ray spectral bands. The sun's energy is radiated uniformly in all directions. Because the Sun is about 150 million kilometres from the Earth, and because the Earth is about 6300 km in radius, only 0.000000045% of this power is intercepted by our planet. This still amounts to a massive 1.75 x 1017 watts. For the purposes of solar energy capture, we normally talk about the amount of power in sunlight passing through a single square metre face-on to the sun, at the Earth's distance from the Sun. The power of the sun at the earth, per square metre is called the **solar constant** and is approximately 1370 watts per square metre (W m-2).

The solar constant actually varies by +/- 3% because of the Earth's slightly elliptical orbit around the Sun. The sun-earth distance is smaller when the Earth is at perihelion (first week in January) and larger when the Earth is at aphelion (first week in July). Some people, when talking about the solar constant, correct for this distance variation, and refer to the solar constant as the power per unit area received at the average Earth-solar distance of one "Astronomical Unit" or AU which is 149.59787066 million kilometres. There is also another small variation in the solar constant which is due to a variation in the total luminosity of the Sun itself. This variation has been measured by radiometers aboard several satellites since the late 1970's.

The graph below is a composite graph produced by the World Radiation Centre and shows that our Sun is actually a (slightly) variable star. The variation in the solar constant can be seen to be about 0.1% over a period of 30 years. Some researchers have tried to reconstruct this variation, by correlating it to sunspot numbers, back over the last 400 years, and have suggested that the Sun may have varied in its power output by up to one percent. It has also been suggested that this variation might explain some terrestrial temperature variations. It is interesting to note that the average G-type star (the class of star the Sun falls into) typically shows a much *larger* variation of about 4%.



Solar Radiation Measuring Instruments (Radiometers)

A radiometer absorbs solar radiation at its sensor, transforms it into heat and measures the resultingamount of heat to ascertain the level of solar radiation. Methods of measuring heat include taking out heatflux as a temperature change (using a water flow pyrheliometer, a silver-disk pyrheliometer or a bimetallic pyranograph) or as a thermoelectromotive force (using a thermoelectric pyrheliometer or a thermo electric pyranometer). In current operation, types using a thermopile are generally used.

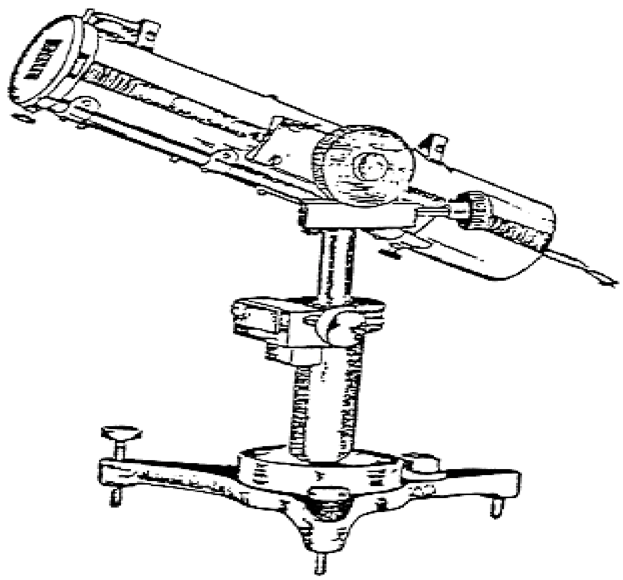
The radiometers used for ordinary observation are pyrheliometers and pyranometers that measure directsolar radiation and global solar radiation, respectively, and these instruments are described in this section.For details of other radiometers such as measuring instruments for diffuse sky radiation and net radiation,refer to ”Guide to Meteorological Instruments and Observation Methods” and “Compendium of LectureNotes on Meteorological Instruments for Training Class III and Class IV Meteorological Personnel”published by WMO.

Pyrheliometers

A pyrheliometer is used to measure direct solar radiation from the sun and its marginal periphery. Tomeasure direct solar radiation correctly, its receiving surface must be arranged to be normal to the solardirection. For this reason, the instrument is usually mounted on a sun-tracking device called an equatorialmount.

The structure of an **Angstrom electrical compensation pyrheliometer**is shown in Figure.

This is a reliable instrument used to observe direct solar radiation, and has long been accepted as a workingstandard. However, its manual operation requires experience.



This pyrheliometer has a rectangular aperture, two manganin-strip sensors (20.0 mm × 2.0 mm ×0.02 mm) and several diaphragms to let only direct sunlight reach the sensorThe sensor surface is painted optical black and has uniform absorption characteristics forshort-wave radiation. A copper-constantan thermocouple is attached to the rear of each sensor strip, andthe thermocouple is connected to a galvanometer. The sensor strips also work as electric resistors and
generate heat when a current flows across them.

When solar irradiance is measured with this type of pyrheliometer, the small shutter on the front face ofthe cylinder shields one sensor strip from sunlight, allowing it to reach only the other sensor. Atemperature difference is therefore produced between the two sensor strips because one absorbs solarradiation and the other does not, and a thermoelectromotive force proportional to this difference inducescurrent flow through the galvanometer. Then, a current is supplied to the cooler sensor strip (the oneshaded from solar radiation) until the pointer in the galvanometer indicates zero, at which point thetemperature raised by solar radiation is compensated by Joule heat. A value for direct solar irradiance isobtained by converting the compensated current at this time. If S is the intensity of direct solar irradiance and i is the current, then S = Ki2,

where K is a constant intrinsic to the instrument and is determined from the size and electric resistance ofthe sensor strips and the absorption coefficient of their surfaces. The value of K is usually determinedthrough comparison with an upper-class standard pyrheliometer.

Pyranometers:

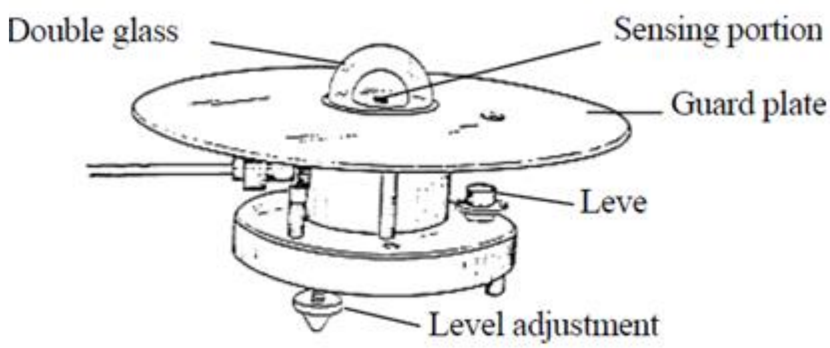
A pyranometer is used to measure global solar radiation falling on a horizontal surface. Its sensor has ahorizontal radiation-sensing surface that absorbs solar radiation energy from the whole sky (i.e. a solid angleof 2π sr) and transforms this energy into heat. Global solar radiation can be ascertained by measuring thisheat energy. Most pyranometers in general use are now the thermopile type, although bimetallic pyranometers are occasionally found.

Thermoelectric pyranometer is shown in Figure. The instrument's radiation-sensing element has basically the same structure as that of a thermoelectric pyrheliometer. Another similarity is that the temperature difference derived between the radiation-sensing element (the hot junction) and the reflectingsurface (the cold junction) that serves as a temperature reference point is expressed by a thermopile as anthermoelectromotive force. In the case of a pyranometer, methods of ascertaining the temperaturedifference are as follows:

1) Several pairs of thermocouples are connected in series to make a thermopile that detects the temperature difference between the black and white radiation-sensing surfaces.

2) The temperature difference between two black radiation-sensing surfaces with differing areas Isdetected by a thermopile.

3) The temperature difference between a radiation-sensing surface painted solid black and a metallic block with high heat capacity is detected by a thermopile.



Sunshine recorder

The duration of bright sunshine in a day is measured by means of sun shine recorder. The sun's rays are focused by a glass sphere to a point on a card strip held in a groove in spherical bowl mounted concentrically with the sphere.Whenever there is a bright sun shine the image formed is intensive enough to burn a part on the card strip. through out the day as sun moves across the sky, the image moves along the strip. Thus, a burnt trace whose length is proportional to the duration of sun shine is obtained on the strip.

Solar Radiation Data

Most radiation data is measured for horizontal surfaces. As shown in figure. It is seen a fairly, smooth variations with the maximum occurring around noon is obtained on a clear day.In contrast an irregular variation with many peaks and valleys may be obtained on a cloudy day.

- Peak values are generally measured in April or may with parts of Rajasthan or Gujarat receiving over 600 Langley's per day.
- During the monsoon and winter months, the daily global radiation decreases to about 300- 400 longley per day.
- Annual average daily diffuse radiation received over the whole country is around 175 longlays per day.
- The maximum value is about 300 langleys in Gujarat in July, while the minimum values between 75 and 100 langleys per day, are measured over many parts of the country during November and December as winter sets in.

Solar radiation on tilted surface:

The rate of receipt of solar energy on a given surface on the ground depends on the orientation of the surface with reference to the sun.A fully sun – tracking surface that always faces the sun receives the maximum possible solar energy at the particular location.

A surface of the same area oriented in any other direction will receive a smaller amount of radiation because solar radiation is such a dilute form of energy, it is desirable to capture as much as possible on a ground area.Most of the solar collectors or solar radiation collecting devices are tilted at an angle to horizontal surface with Y=0 facing south for tilted surface.

$$\cos\theta = \sin\delta \sin(\phi - s) + \cos\delta \cos\omega \cos(\phi - s)$$

For horizontal surfaces $\cos\theta_Z = \sin\phi \sin\delta + \cos\phi \cos\delta \cos\omega$

Tilt factor for beam radiation

$$\Upsilon_b = \frac{\cos\theta}{\cos\theta Z}$$

$$\Upsilon_d = \left[\frac{1+\cos s}{2}\right]$$