

UNIT-I PRINCIPLES OF SOLAR RADIATION

**Role and potential of new and renewable source**

India has supply, 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, 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, MNE S was named 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
- o Pressure on high-emission industry sectors from their shareholders
- o Available 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 one of the leading destinations for investors from developed countries. This attraction is partially due to the lower cost of man power and good quality production. The expansion of investments has brought benefit so 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. There mining populations 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, with significant development already in the planning stages. This report gives an overview of their renewable energies market in India. We look at the current status of renewable market in India, the energy needs of the country, forecasts of consumption and production, and whether India can power its growth and its society with renewable resources.

The Ministry of Power has 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 conventional generating option 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<sub>2</sub> emissions, and, normally, absence of any air emissions or waste products during their operation. Concerning the environment, these are of SET as additional positive implications such as:

- \* Reduction of the emissions of the greenhouse gases (mainly CO<sub>2</sub>, NO<sub>x</sub>) and prevention of toxic Gas emissions (SO<sub>2</sub>, particulates)
- \* Reclamation of degraded land;
- \* Reduction of their retransmission 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 research institutions, public sector institution, BHEL and Central Electronic Limited and carrying out 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 seawater
6. Solar cookers
7. Solar engines for water pumping
8. Food refrigeration
9. Bioconversion and wind energy and which are indirect sources of solar energy
10. Solar furnaces
11. Solar electric power generation by
  - i) Solar ponds
  - ii) Steam generators sheeted 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%

**Sources**

- NUCLEAR - 2.7%
- RENEWABLE - 10.42% WIND CAPA
- CITY - 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

*Solar Radiation*

Solar energy, received in the form of radiation, can be converted directly or indirectly into their forms of energy, such as heat and electricity. The major drawbacks of the extensive application of solar energy are

1. The intermittent and variable manner in which it arrives at the earth's surface and
2. The large area required 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 micrometer (1 micrometer =  $10^{-6}$  meter)

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

- 8% ultraviolet radiation [short wavelength > 0.39 micrometer]
- 46% visible light [0.39 to 0.78 micrometer]
- 46% infrared [0.78 micrometer 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  $1.39 \times 10^6$  km while that of earth is  $1.27 \times 10^4$  km. The mean distance between the two is  $1.5 \times 10^8$  km. Although the sun is large, its subtended angle of only 32 min. at the earth's surface.

The brightness of the sun varies from its center to its edge. However, for calculation purposes 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 is received at the top. 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 closest to the sun during the summer and farthest during the winter.

Sources

This variation in distance produces sinus variation in the intensity of solar radiation that reaches.

$$I_{SC} = 1367 \text{ watts/m}^2$$

$$I_{SC} = 1367 \cos \left( \frac{2\pi}{365} \cdot \text{day} \right) \quad \text{Where is the day of the year.}$$

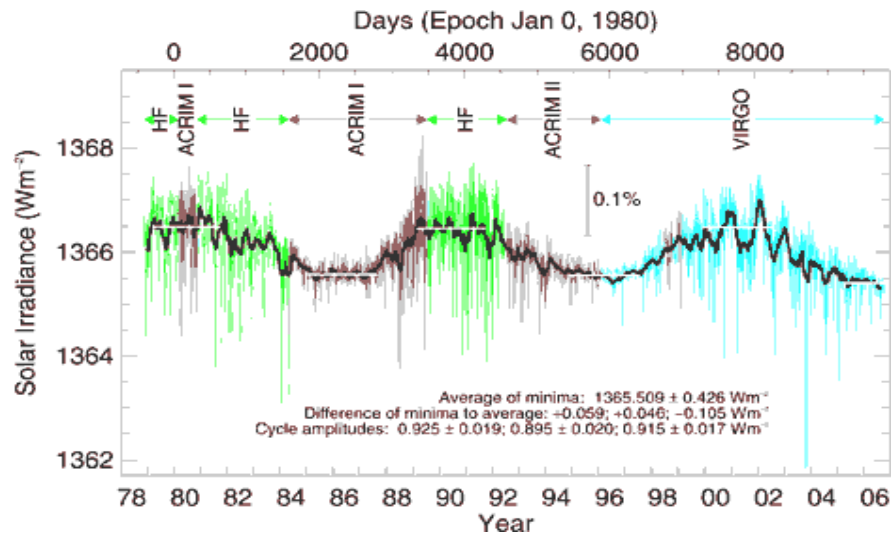
Spectral distribution of solar radiation intensity at the outer limit of the atmosphere

The luminosity of the Sun is about  $3.86 \times 10^{26}$  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-rays spectral bands. The sun's energy is radiated uniformly in all directions. Because the Sun is about 150 million kilometers from the Earth, and because the Earth is about 6300 km in radius, 0.00000045%. This still amounts to a massive  $1.75 \times 10^{17}$  watts. For the purposes of solar energy capture, we normally talk

about the amount of power in sunlight passing through a single square meter face-on to the sun, at the Earth's distance from the Sun. The power of the sun at the earth, per square meter, is called the solar constant and is approximately 1370 watts per square meter ( $\text{Wm}^{-2}$ ).

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 kilometers.

There is also another small variation in the solar constant which is due to 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%.



*SolarRadiationMeasuringInstruments(Radiometers)*

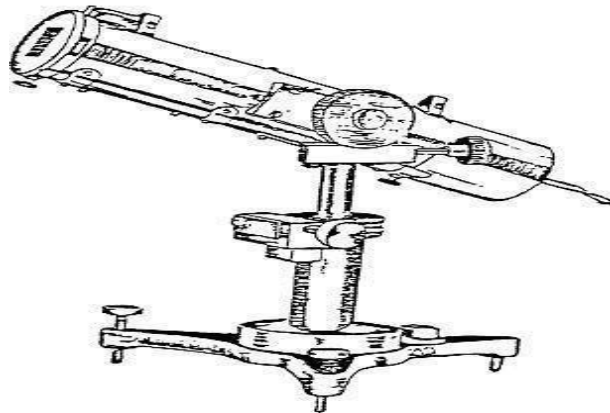
A radiometer absorbs solar radiation at its sensor, transforms it into heat and measures the resulting amount of heat to ascertain the level of solar radiation. Methods of measuring heat include taking out heat flux as a temperature change (using a water flow pyr heliometer, a silver-disk pyr heliometer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

The radiometers used for ordinary observation are pyr heliometers and pyranometers that measure direct solar 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 Lecture Notes on Meteorological Instruments for Training Class III and Class IV Meteorological Personnel" published by WMO.

**Pyr heliometers** A pyr heliometer is used to measure direct solar radiation from the sun and its marginal periphery. To measure direct solar radiation correctly, its receiving surface must be arranged to be normal to the solar direction. For this reason, the instrument is usually mounted on a sun-tracking device called an equatorial mount.

The structure of an Angstrom electrical compensation pyr heliometer is shown in Figure.

This is a reliable instrument used to observe direct solar radiation, and has long been accepted as a working standard. 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 sensor. The sensor surface is painted optical black and has uniform absorption characteristics for short-wave radiation. A copper-constantan thermocouple is attached to the rear of each sensor strip, and the 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 of the cylinder shields one sensor strip from sunlight, allowing it to reach only the other sensor. A temperature difference is therefore produced between the two sensor strips because one absorbs solar radiation and the other does not, and a thermoelectromotive force proportional to this difference induces current flow through the galvanometer. Then, a current is supplied to the cooler sensor strip (the one shaded from solar radiation) until the pointer in the galvanometer indicates zero, at which point the temperature raised by solar radiation is compensated by Joule heat. A value for direct solar irradiance is obtained by converting the compensated current at this time. If  $S$  is the intensity of direct solar irradiance and  $i$  is the current, then  $S = Ki^2$ , where  $K$  is a constant intrinsic to the instrument and is determined from the size and electric resistance of the sensor strips and the absorption coefficient of their surfaces. The value of  $K$  is usually determined through 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 a horizontal radiation-sensing surface that absorbs solar radiation energy from the whole sky (i.e. a solid angle of  $2\pi$  sr) and transforms this energy into heat. Global solar radiation can be ascertained by measuring this heat energy. Most pyranometers in general use are now the thermopile type, although bimetallic pyranometers are occasionally found.

A thermo-electric 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 reflecting surface (the cold junction) that serves as a temperature reference point is expressed by a thermopile as a thermoelectromotive force. In the case of a pyranometer, methods of ascertaining the temperature difference 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 is

detected 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 Corder*

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



*SolarRadiationData*

Most radiation data is measured for horizontal surfaces. As shown in figure, it is seen a fairly smooth variation 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 Langleys per day.
- During the monsoon and winter months, the daily global radiation decreases to about 300–400 Langleys per day.
- Annual average daily diffuse radiation received over the whole country is around 175 Langleys 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.

*Solarradiationontilted 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  $\gamma = 0$  facing south for tilted surface.*

$$\cos \vartheta = \sin \delta \sin (\varphi - s) + \cos \delta \cos \omega \cos (\varphi - s)$$

$$\text{For horizontal surfaces: } \cos \vartheta Z = \sin \varphi \sin \delta + \cos \varphi \cos \delta \cos \omega$$

$$\text{Tilt factor for beam radiation: } \gamma_b = \cos \vartheta / \cos \vartheta Z$$

$$\gamma = [1 + \cos s] / d^2 \sqrt{566}$$

