



Analysis of Meteorological Parameters for Solar Radiation Resource Assessment

¹C. Subba Rami Reddy, ²Pedda Suresh Ogeti³N. Bhoopal,

^{1,2,3}EEE department,

^{1,3}B.V. Raju Institute of Technology,

Narsapur, Medak, Telangana-502313

²Hyderabad Institute of Technology and Management

¹csubbaramireddy2020@gmail.com,

²peddasureshogeti@gmail.com,

³bhoopal.neerudi@bvr.it.ac.in

May 2, 2018

Abstract

The solar radiation is optimally utilized by relating to measuring instruments and sensors. Using the data of meteorological parameters, the analysis presented here is used in worlds largest Direct Normal Irradiance (DNI) measurements network of 51 meteorological stations. For validating solar radiating models data is required to design and develop Solar Energy Systems (SES). SES depends on radiometric measurements and instrumentation for developing solar models. In literature, pyranometer strongly deviates diffuse and global radiation measurements, particularly in winter, unless appropriate corrective measures are taken. Other types of measurement problems are also discussed, such as those involved in the indirect determination of direct or diffuse irradiance. To estimate the DNI the parameters taken are diffused radiation, global radiation, wind speed, direct radiation, wind direct, air temperature, relative humidity and the plots has been analysed annually and for one corre-

sponding day. The data has been collected by using Global Positioning system (GPS) technique.

Key Words: Direct Normal Irradiance, meteorological parameters, pyranometer, diffused radiation, global radiation, Global Positioning system.

1 Introduction

According to a survey, in most of the rural areas, electricity supply is not sufficient or even it does not exist. Therefore, solar energy is harnessed to meet the electricity demand. Literature survey on various solar activities, solar and meteorological parameters, sensors, measuring instruments and auxiliary equipment have been focussed. As an efficient, clean and pollution free, solar energy is the first choice to solve the energy and environmental problems in the future. To develop solar energy industry is an effective means of improving peoples living standards. Solar radiation resource assessment is very helpful for installing the solar panels in appropriate place for extracting the power in remote areas where distribution network is not possible. Solar radiation resource assessment is done by calculating the solar radiation by considering the geographical and ecological environment. The data is collected by using the GPS technique [1]. The quality and quantity of measured solar radiation data has varied greatly. Current radiometers still use old technology, with relatively small fundamental improvements. The building roof where solar panel is installed should be an open area; no tree is near to it. The buildings are protected from the snow in winter to obtain appropriate annual solar energy estimation [2]. Tracking system is used for maximization of the direct solar radiation. Pyranometer and pyroheliometer are used with the tracking system to get more solar radiation [3]. In [4], radiation tolerant space suitable SRAM-based FPGAs are implemented for hardware setup. The sample values of all the meteorological parameters are taken from APEX Institute of Technology and Management, Bhubaneswar.

The paper has been organised as follows. In section II, the system installed has been presented, in section III, principles, measuring instruments and the meteorological parameters has been elaborated, in section IV, the parameters has been analysed and concluded in the next section.

2 System description

A schematic diagram of the system under consideration is shown in Figure 1. It is having a meteorological tower which is installed in the roof, a lightning arrestor tower, a solar tower, a solar pv panel and a rain gauge. The meteorological tower is having a height of 6m. It consists of a GPRS antenna, an ultrasonic wind sensor, a global positioning system, a rain gauge, temperature sensor, data logger and modem and battery. The lightning arrestor is having a surge diverter so as to protect the system. The solar tower is having two pyranometeri.e, one with having a shading assembly and another without shading assembly support, a pyrhelimeterand a solar tracker. It is having a height of 1.5m.

3 Meteorological Parameters

The various parameters taken into account areSolar Irradiance. In eq(1),hourly global solar irradiance function is defined as the beta probability distribution function (PDF) [5],

$$f_{I_x}(i_x; \alpha, \beta) = \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha)\Gamma(\beta)} \left(\frac{i_x}{I_0}\right)^{\alpha-1} \left(I - \frac{i_x}{I_0}\right)^{\beta-1} \quad (1)$$

where i_x is the solar irradiance (w/m^2), $\Gamma(\cdot)$ is the gamma function, α and β are the shape parameters of the beta distribution, I_0 is the extraterrestrial solar irradiance (w/m^2), $f_{I_x} i_x$ is the PDF of the solar irradiance random variable I_x

Eq (1) signifies an hourly random variable which is defined as the ratio of global to extraterrestrial solar irradiance of that hour. The random variable gives the measure of clearness index.



Fig.1. Solar Monitoring System

$$I_0 = 1367 \left(\frac{\bar{D}}{D} \right)^2 \quad (2)$$

Where $\bar{D}$ denotes yearly mean distance between the sun and the earth, D is the daily distance between the sun and the location. The extraterrestrial radiation average is taken as 1367 w/m^2 and is varying throughout the year by 3% as the earth completes one orbit around the sun.

$$\begin{aligned} \left(\frac{\bar{D}}{D} \right)^2 = & 1.00011 + 0.034221 \cos(\beta) + 0.00128 \sin(2\beta) \\ & + 0.000719 \cos(2\beta) + 0.000077 \sin(2\beta) \end{aligned} \quad (3)$$

$$\beta = \frac{2\pi n}{365} \quad (4)$$

where β is the rotational angle taken by earth around the sun, n is the particular day in the year starting from 1 to 365 or 366 for leap years.

Direct Normal Irradiance is the irradiance of the sun emitted from the solid angle of the sun's disc, received by a unit surface held perpendicular to the solar beam. It includes a small quantity of irradiance that is scattered by the intervening medium along the axis of the cone [6]. If there is any attenuation then it will be due to

the variation in the relative concentration of individual constituents of the medium i.e., air.

Diffuse Solar Irradiance is the downward irradiance scattered by the atmospheric constituents and deflected and incident on a unit horizontal surface when transmitted through the clouds. This irradiance comes from the surface of whole hemisphere of solid angle of 2π by the sun's disc with the subtended exception of the solid angle.

Global Solar Irradiance is the irradiance that reaches horizontal unit surface. It is made up of the direct normal irradiance and scattered diffuse solar irradiance. When a parallel beam of radiant flux spreads over a flat surface of a given cross sectional area, the area covered by it is inversely proportional to cosine of angle taken at the normal to the surface.

Measuring Instruments

Pyrheliometer measures the direct normal solar irradiance. The solar radiation is incident perpendicularly on the receiving surface. The normal incidence is achieved by mounting it on the solar tracker, in case of instantaneous measurements. The construction of the pyrheliometer mounting will allow for the smooth and rapid adjustment of the elevation and azimuth angles. A sighting device is included in which a small spot of light or solar image falls upon a mark in the centre of the target when the receiving surface is exactly normal to the direct solar beam.

Pyranometer is a sensor designed for measuring the solar radiation flux density (W/m^2) from a field view of 180° . This is used to measure broadband solar irradiance on a planar surface. Pyranometers normally consist of photoelectric, thermo-electric, bimetallic elements or pyro-electric devices as sensors [7]. Pyranometers are robust in construction and even capable of resisting the corrosion effects under humid air and bad weather conditions. The receiver is sealed hermetically inside its casing and can be easily taken out for removing any condensed moisture as shown in Fig.2.



Fig.2. Pyranometer

Solar Tracker is used for tracking the sun and is used for receiving maximum radiation. The solar panel is rotated according to the movement of sun, the maximum radiation can be received. The solar tracker is having one pyrliometer and two pyranometers. A shading assembly on solar tracker blocks the direct solar radiation mounted on the tracker from reaching the pyranometer so that the diffuse solar radiation from the sky can be measured. One pyranometer with shading assembly support for diffuse radiation measurement and another pyranometer without shading assembly support for global radiation measurement.

Sensors and Equipments

Relative Humidity Sensor is used to determine the amount of watervapour present in air and this sensor is a function of temperature. Since water vapour in the air affects the density, so the use of relative humidity sensor can improve the accuracy of air density estimates. Atmospheric Pressure Measurement Sensor is used to measure the atmospheric pressure also called as barometric pressure sensors (barometer). It is also called a high altitude compensator. Atmospheric pressure varies with weather and altitude. At higher elevations the air is less dense, so it has less pressure. The weather also changes the air pressure. **Rainfall Sensor:** Rain gauge is used for measuring the precipitation which occurs due to rain on earth's surface. The rain gauge comprises a siphoning mechanism which tends the rain to fall at a steady rate to the tipping bucket. The tipping bucket system measures the rainfall intensity, so that typical rain bucket errors are reduced and enables the gauge to record intense rainfall events.

GPS: The Global Positioning System is a space-based satellite navigation system which provides time information and location for all weather conditions, on or surrounding the earth. It is used to synchronize sun tracker with sun movement. **GPRS:** The General Radio Packet Service is a very efficient and inexpensive method for transmitting wind, meteorological and turbine data in real time. The displayed data is controlled and monitored by some parameters from a remote distance over the Internet.

4 Results

Table.1 the following are the sample data values of the meteorological parameters taken on 12th Feb,2017 in APEX building in Bhubaneswar.

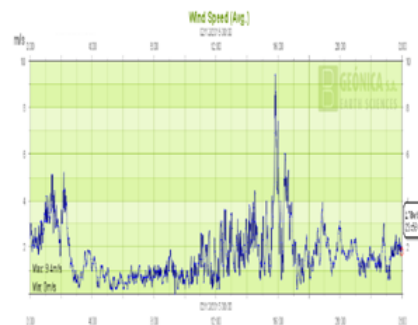


Fig.3. wind speed vs time

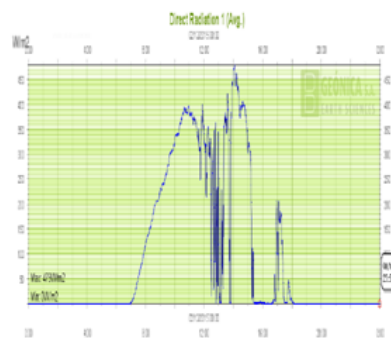


Fig.4. Diffuse radiation vs time

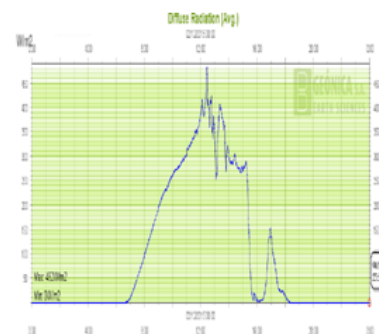


Fig.5. Direct radiation vs time

Table.1 Meteorological Parameters Values

Meteorological Parameters	Values
1.Wind speed (Avg)	2.9 m/s
2.Diffused Radiation (Avg)	348 W/m ²
3.Global Radiation1 (Avg)	798 W/m ²
4.Direct Radiation1 (Avg)	528 W/m ²
5.Wind Direction (Avg)	269°
6.Air Temperature (Avg)	28°C
7.Relative Humidity (Avg)	52%
8.Dew Point (Avg)	17.2°C
9.Atmospheric Pressure QFE	1007.7 mb
10. Atmospheric Pressure (Avg)	1095 mb
11. Pyrheliometer Error1	1.5%
12. Rain (Accu)	0 mm
13. Access C (Logic OR)	0 Status
14. Geo3K.Stat (Logic OR)	0 Status
15. Battery (Avg)	13.56 V

Table. 2. The following are the sample values of DNI taken in each month of the year 2017.

Months	DNI MonthlyAvg
January	4.67
February	6.33
March	6.1
April	5.92
May	4.88
June	2.61
July	1.12
August	1.68
September	2.607
October	4.612
November	4.219
December	4.505

Fig.3 shows the wind speed on 12th February 2017 for the whole day(24 hours), and is found that the wind speed is maximum at 16:00 hrs and in Fig.5 it is found that the direct radiation and the diffuse radiation is maximum at 12:30PM and the maximum power can be extracted, since sun radiations are maximum in the mid day.

In Table.2, annual (2016) data has been given for DNI for the installation set up in APEX Institute of Technology and Management shown in Fig.1. Average DNI for each month in 2016 has been given in Table.2 and has been plotted in Fig.6.

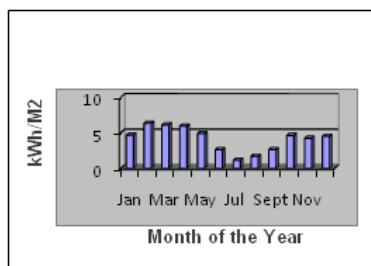


Fig.6 DNI (KWh/m2) vs Months (2016)

5 Conclusion

This paper shows how to get the solar energy by using the different meteorological parameters, sensors and equipments. The analysis of all the meteorological parameters and the values are shown in the form of graphs. Main focus has been emphasised on DNI and its analysis, since maximum power from solar panel can be extracted from DNI radiations. Plots have been discussed for annual data of DNI for 2016 data. Solar radiation resource assesment is very helpful for installing the solar panels in appropriate place for extracting the power in remote areas where distribution network is not possible.

References

- [1] Ruren Li, XiaohuiLiu,Yuqiang Sun, Integrated assessment model for solar energyresource based on GIS, IEEE Conference 2010.
- [2] YuanfanZheng and QihaoWeng, Assessing Solar Potential of Commercial and Residential Buildings in Indianapolis usingLiDAR and GIS modelling, 2014ThirdInternational Workshop on Earth Observation and Remote Sensing Applications IEEEConference 2014.

- [3] LaurentiuAlboteanu, Florin Ravigan,AlexandruNovac, Design of a Sun TrackingAutomaton for Photovoltaic Panels with Low Concentration of Solar Radiation, IEEE Conference 2014.
- [4] BjrnFiethe, Frank Bubenhausen, Tobias Lange, HaraldMichalik, Holger Michel, JoachimWoch, Johann Hirzberger, Adaptive Hardware by Dynamic Reconfiguration for the Solar Orbiter PHI Instrument, 2012 NASA/ESA Conference on Adaptive Hardware and Systems,IEEE Conference 2012, pp. 31-37.
- [5] Arash M. Dizqah, AlirezaMaheri, Krishna Busawon, An Assessment of Solar Irradiance Stochastic Model for the UK, 2012 2nd International Symposium on Environment- friendly Energies and Applications,IEEE Conference 2012, pp. 670-675.
- [6] Syafawati A.N, Salsabila A, Farhana Z., Arizadayana Z., RazlianaN., Norjasmi A.R.,Muzaidi O., S.Akhmal, Forecasting the Potential of Solar Energy Harvest in Kangar,2013 IEEE 7th International Power Engineering and Optimization Conference, pp. 77-82.
- [7] BianZeqiang, Lu Wenhua, ShaYizhuo, He Xiaolei, Chong Wei, Research on Performance Test Method of Silicon Pyranometer, the 11th IEEE International Conference on Electronic Measurement & Instruments, 2013,pp. 43-48.