Ayodele S. A., 2023, 11:5
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

Estimation of the Global Solar Radiation in Anyigba Kogi State Using Angstrom-Prescott Model

Ayodele S. A., Adeyemi J. O., Ohiani O.A.
Department of Physics, Prince Abubakar Audu University, Anyigba-Nigeria

Abstract: Global Solar radiation data is a very important data, useful for solar energy installation and agriculture. Angstrom Prescott model was used to estimate the global solar radiation for Anyigba using the latitude of the area which is 7.4809 and the sunshine hour. The Angstrom Prescott model for Anyigba was found to be $\underline{H_O}$= (0.2324+0.6656(n/N)). The regression coefficient a and b were found to be 0.2324 and 0.6656 respectively. The result was validated using a 6years global solar radiation data between years 2011 to 2016.

Keywords: Angstrom-Prescott, Global Solar Radiation, Extraterrestrial Solar Radaiation, Clear Sky Index

I. INTRODUCTION

Solar radiation is an important phenomenon which can be utilized to generate electricity called solar energy. Solar radiation is the energy which spreads out from the sun and is measured in killomatt per square meter. Solar radiation hitting the surface of the atmosphere is vertical to the direction of propagation. Solar radiation reaching the top of the atmosphere is about 1367 W/m^2 , this is called solar constant. The solar constant has an uncertainty of 1%. Nigeria records an average of about 20MJ/m^2, which is a funtion of location and the time of the year (Nwokoye, 2006).

Solar radiation is abundant in Nigeria, this is because of the location of Nigeria being at the arround the tropics. There is need for a continuous effort to harness the abundant natural resourses available, to complement the energy mix and figt againt adverse environmental impact such as global warming and climate change (Ibeh*et al.*, 2012).

Global Solar radiation recordeded in a location is divided into components which are the direct normal irradiance(DNI), and the diffuse horizontal irradiance. The combination of the direct normal irradiance (DNI) and diffuse horizontal irradiance (DHI) is global horizontal irradiance (GHI). Global solar radiation is essensial in the design and simulation of solar energy installations in terrm of the evaluation of the available solar resources in the location , it is also importan in plant growth as in the study of plants evapotranspiration and architectural design. (Ahmad, F., *et al.,* 2004). In order to acquire global solar radiation data in a particular location, installation of weather station of instrument is required, solar radiation data are easily acqired when the location is closer to a meteorological station. Setting up weather station is capital intensive and comes with the challenge of maintenance and recallibration, therefore empirical models can be used to estimate global solar radiation without weather station using available meteorological factors, (Abdu and Ayodele 2016). A number of researchs employed quit a number of empirical models to estimates global solar radiation in different locations, example of such model is the linear and quadratic angstrom Prescott model, the Hargreave and Samini model. This models uses environment variables such as (solar constant, world-sun distance, solar declination and hour angle); geographical factors (latitude, longitude and altitude); geometrical factors (surface azimuth, surface tilt angle, solar altitude, solar azimuth); physical factors (albedo, scattering of air molecules, water vapor content, scattering of dust and other atmospheric constituents); and meteorological factors (atmospheric pressure, cloudiness, temperature, sunshine duration, air temperature, soil temperature, relative humidity, evaporation, precipitation, number of rainy days, total precipitable water, etc. (Almorox, J., *et al.,* 2004),(Menges, H.O., *et al.*, 2006), and (Almorox, J., *et al.,* 2008).

II. AIM AND OBJECTIVES

The Aim of this study is to evaluate the solar radiation in Anyigba, Kogi state, using Angstrom-Prescott Model, with the objectives of the study

I. To obtain the solar radiation data from the Centre for Atmospheric Research.
II. To determine the regression coefficient of Angstrom Prescott model for Anyigba
III. To evaluate the uncertainty between the solar radiation data and the estimated global solar radiation estimated using Angstrom-Prescott model.

Scope of the study This study will be carried out in the geographical area of Anyigba (7.4809°N and 6.9°E) and an altitude of 420metres above sea level. Six (6) years solar radiation data (2011-2016) will be used for this work. The availability and variability of solar radiation will be analyzed using Angstrom-Prescott Model

III. MATERIALS AND METOD

Angstrom–Prescott Model

Angstrom Prescott was the first researcher that proposed a correlation for estimating monthly average daily global solar radiation in 1924, who derived a linear relationship between the ratio of average daily global radiation to the corresponding value on a completely clear day ($\frac{H}{Hc}$) at a given location and the ratio of average daily sunshine duration to the maximum possible sunshine duration given as:

$$\frac{H}{Hc} = a+b(\frac{S}{So}) \quad (1)$$

Where:

H is the monthly average daily global radiation,

H_c is the monthly average clear sky daily global radiation,

S is the monthly average daily hours of bright sunshine (h),

So is the monthly average day length (h),

a and b are empirical coefficients.

The above equation was most widely used correlation but there is some basic difficulty which lies in the definition of the term H_c and the others have modified the method that replace the term H_c with extra-terrestrial radiation on a horizontal surface $H_o$rather than on clear day radiation and therefore proposed the following relation(Abdu and Ayodele, 2016)

$$\frac{H}{Ho} = a+b(\frac{S}{So}) \quad (2)$$

$$a = -0.110 + 0.235\ cos\ cos\varphi\ + 0.323(\frac{S}{So}) \ (3)$$

$$b = 1.449 - 0.553\varphi - 0.694(\frac{S}{So}) \ (4)$$

(a and b are the regression coefficient)

Ho is the monthly average daily extra-terrestrial radiation; the values of the monthly average daily extra-terrestrial irradiation (H_o) can be calculated from the equation given below as

$$H_o=\frac{24}{\pi}I_{sc}[1+0.033\cos(\frac{360n}{365})] [\cos\varphi\cos\delta\sin\omega_s+\frac{\pi}{180}\omega_s\sin\varphi\sin\delta] \ (5)$$

Where:

I_{sc} is the solar constant (1367Wm^{-2}),

φ is the latitude of the site,

δ is the solar declination,

ω_s is the mean sunrise hour angle for the given month

n is the number of days of the year starting from first January.

The solar declination (δ) and the mean sunrise hour angle (ω_s) can be calculated by following equations:

$$\delta = 23.45\sin[360/365(284+n)] \quad (6)$$

H_0 is the extraterrestrial radiation (radiation intensity outside the earth's atmosphere) measured in mega joule per square meter per day (MJm^{-2} day^{-1}), d is the day of the year i.e. the Julian day calculated every 15th of each month.

$$n = INT\left(\frac{275 \times M}{9}\right) - K \times INT\left(\frac{M+9}{12}\right) + D - 30 \ (7)$$

Where M is the month number, D is the day of the month, and K=1 for a leap year, K=2 for a common year. INT means taking the integer part of the number

$$\omega_s=\cos^{-1}(-\tan\varphi\tan\delta) \ (8)$$

The maximum possible sun-shine duration (monthly average day length, S_0) can be computed by using the following equation:

$$\mathbf{S_0} = \frac{2}{15\omega s} \quad (9)$$

IV. RESULT AND DISCUSION

TABLE 1: This table shows the months, the extraterrestrial solar radiation (H_O), the calculated and measured mean monthly global solar radiation,. The mean global radiation is measured in MJ/M^2

Table 1. Extraterrestrial solar radiation (H_O)

MONTH	H_O	S_O	$H_{j,calculated}$	$H_{j,measured}$
January	32.9788	0.6483	16.70359	16.402
February	35.2930	0.7359	18.08151	19.4216
March	37.2209	0.6483	19.28629	20.9286
April	37.7024	0.5782	21.07485	22.3609
May	36.8846	0.6133	16.74602	20.8980
June	36.1095	0.5607	15.13066	16.1654
July	36.3333	0.4643	14.37671	15.7878
August	37.1392	0.3504	12.31344	13.6800
September	37.1568	0.4293	12.53597	16.0092
October	35.6608	0.5957	15.5665	17.2066
November	33.3858	0.7359	16.90969	17.5666
December	32.1839	0.7272	16.67632	16.2436

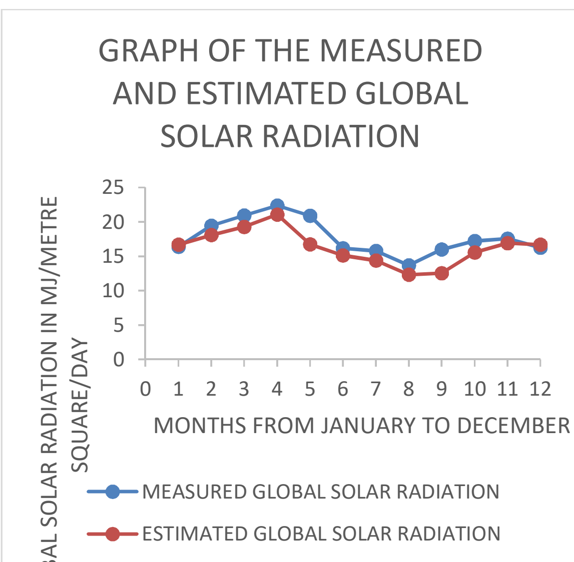

FIG.2 The graph of the measure global solar radiation and estimated global solar radiation using Angstrom Prescott model

V. DISCUSSION

This research is aimed at estimating the global solar radiation in Anyingba using angstrom Prescott model and evaluating the regression coefficient using the latitude of the location and the mean daily sunshine duration. Table one table shows the extraterrestrial average monthly solar radiation, the second column on the table represents the relative solar duration and lastly the calculated and measured global radiation respectively. The graph compares the measured and calculated global solar radiation. It can be seen that the highest solar global radiation occurs in the month of April which corresponds with the highest clear sky index value and the lowest month in the year happens to be August which corresponds with the lowest clear sky index value, this is as a result of the rain fall in August month.

VI. CONCLUSION

The Angstrom Prescott regression constant **a** and **b** for Anyigba was found to be 0.2324 and 0.6656 respectively, therefor the Angstron Prescott model is found to be $\underline{H_O}$= (0.2324+0.6656(n/N)). The graph on figure one showed that Angstrom Prescott model is suitable for the estimate of the global solar radiation as in Anyigba as the result of the MBE and RMSE which falls within acceptable range and the agreement between the estimated and measured monthly mean of the daily global solar radiation. The MBE and RMSE was found to be - 1.4391 and 1.9100 respectively the yearly average global solar radiation for Anyigba was found to 16.2835 MJ/ M^2 be with an uncertainty value of 2.4397.

REFERENCES

[1]. Abdu G., and Ayodele A.S., (2016). Empirical Model for the Estimation of Monthly Global Solar Radiation in Zaria Nigeria. International journal of physics and mathematical science. Vol 6(4). pp 57-62

[2]. Ahmad, F., Ulfat, I., *(2004). Empirical Models for the Correlation of Monthly Average Daily Global Solar Radiation with Hour of Sunshine on a Horizontal Surface at Karachi, Pakistan. Tuk.J. Physics*. Vol. 28, 301-307.

[3]. Almorox, J., Benito, M., and Hontoria, C., (2004). Estimation of Monthly Angstrom-Prescott

International Journal of Science, Engineering and Technology

An Open Access Journal

Equation Coefficient from Measured Daily Data in Toledo, Spain. Elsevier Renewable Energy Vol. 30, PP 931-936

[4]. Almorox, J., Hontoria, C., (2004). Global Solar Radiation Estimation Using Sunshine Duration in Spain. *Energy Conversion and Management*. Vol. **45**, 1529-1535.

[5]. Akpabio L.E.,Udo, S.O.,Etuk S.E.,(2005) .Modeling global solar radiation for a tropical location: Onne, Nigeria. *Turk. J. Phys*., Vol. 29, PP 63-68.

[6]. Ibeh, G.F., Agbo, G.A., Ekpe, J.E., and Isikiwue, B.C. (2012). Estimation of global Solar Radiation at Calabar using two models. *Journal of Natural Sciences research,* 2(5); Pp. 17-24.

[7]. Menges, H.O., Ertekin, C., Sonmete, H. (2006). Evaluation of Global Solar Radiation Models for Konya Turkey Assessing Monthly *Conversion and Management. Vol.* **47**, pp 3149-3173

[8]. Nwokoye, A.O.C., (2006). Solar Energy Technology: Other Alternative Energy Resources and Environmental science, Rex Charles and Patrick Limited, Nimo; p. 426.