Estimation of Monthly Global Solar Radiation in Anyigba Using Angstrom-Page Model

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Abstract- This work estimates the monthly average global solar radiation for Anyigba with latitude 7.4934^{0}N using Angstrom-page model [$\overline{H}$=0.24+0.48(S_o)]H_o and Angstrom-page model was found to be suitable to estimate the global solar radiation for Anyigba. The Average global solar radiation for Anyigba was found to be 16.28345. The MBE was found to be -1.493518MJm^{-2} and RMSE was found to be 0.0733MJm^{-2} respectively.

Indexed Terms- Angstrom- page model, Monthly Mean Solar Radiation, Extraterrestrial Solar Radiation

I. INTRODUCTION

Energy is essential for human comfort and economic activities, most of the earth's energy source are derived from the sun. Solar energy is sustainable, clean and abundant (Chegaar and Chibani, 2000). The knowledge of the distribution of solar energy on earth is essential for the development of solar power system, which is an important renewable source of energy amongst others (Augustine and Nnabuchi,2010). The amount of solar energy received in Nigeria varies between 5,250 Wh/m^2/day to about 3500 Wh/m^2/day at the coastal areas and about 7000 Wh/m^2/day at the Northern hemisphere of the country. This leaves the average sunshine hour per day in Nigeria to about 6.5 hours. Which is referred to as the sunshine hour (Chineke and Igwiro, 2008).

Having a good record of solar radiation on the earth surface is important in many facet of life beyond just design of solar power system. Solar radiation records are important in the field of study of hydrology, climatology, water irrigation, and design of solar heating systems and cooling. (Tarawneh, 2007).

So many researches have been carried out in different location in Nigeria aiming at estimating the global solar radiation using empirical model such as quadratic, linear Angstrom Prescott model and Hargreaves and samini model.

Sambo, 1985 a developed correlation with solar radiation using sunshine hour Kano and ascertain the regression coefficient a and b to be 0.413 and 0.241 respectively. Abdu an Ayodele (2016) estimated the monthly global solar radiation in zaria - kaduna and found the regression coefficient a and b to be 0.3325 and 0.4510 respectively and concluded that the model is suitable for the particular location.

Innocent *et a*l, 2015 estimated the global solar radiation in Gusau city Nigeria using Angstrom-prescott model and a 6years sun shine data. It was found that the global solar radiation for Gusau is in the range of 16.1676-21.6536 MJm^{-2}day^{-1} hour. In most research literatures available using empirical models available, the model is calibrated to the particular location through the coefficient of regression, little have been explore to ascertain if Angstrom page model which claimed that with a particular coefficient of regression coefficient, the global solar radiation of any location could be found.

II. AIM

The aim of this study is to estimate the global solar radiation in anyigba, Kogi state-Nigeria using Angstrom-page model, ascertaining the agreement between the estimated data to measured data and suitability of Angstrom page model to Anyigba.

III. STUDY AREA

This research would estimate the monthly mean of global solar radiation for Anyigba. The data collection was done using Campbell automatic weather station, located at Kogi State University, Anyigba on the coordinates (7.4934°N, 7.1736°E) in North-Central Nigeria.

IV. MATERIALS AND METHODS

This study employs Angstrom-Page model using solar radiation data between the year 2011 to 2016 and sunshine hour data collected from the weather achieve of the center for atmospheric research, located in Kogi State University Anyigba. The Angstrom page model is presented below in equation (1)

$$\frac{H}{Ho} = 0.24 + 0.48\,\frac{s}{so} \qquad (1)$$

Angstrom–page model is a modification to Angstrom-Prescott model. In 1924, Angstrom proposes a model for the estimation of global solar radiation, that became the first model for the estimation of global solar radiation, this model was modified in 1940 as result of some term in the model like the clear sty global solar radiation which are difficult to obtain due to activities of the cloud. The modified model was called Angstrom-present model. Angstrom-Prescott model is the most widely used correlation for estimating monthly average daily global solar radiation. Almost all the other sunshine-based models are modifications of the Angstrom-Prescott model. The Angstrom-Prescott model is given as:

$$\frac{H}{Ho} = \mathbf{a} + b\,\frac{s}{so} \qquad (2)$$

$$s_o = \frac{n}{N} \qquad (3)$$

The value of H_o can be calculated using the equation given by Abdu and Ayodele, 2016 as:

$$H_o = \overline{H_O} = \frac{24 \times 3600}{\pi} \quad I_{sc}\left[1 + 0.033cos\,\frac{360d}{365}\right] \times \left(cos\varphi\;\; cos\delta\; sin\omega s\; + \frac{\pi}{180}\omega s\; sin\varphi\; sin\delta\right) \qquad (2)$$

Where:

w_s = sunset hour angle in degree defined as:

$$w_s = cos^{-1}(-tan\varphi tan\delta) \qquad (3)$$

δ = declination angle given as:

$$\delta = 23.45\,\sin\left(360 \times \frac{[284+75]}{365}\right) \qquad (4)$$

ø = the latitude of the location;

ɖɳ = day number of the year starting from the first of January;

I_{sc} = Solar constants given as 1367 (Wm^{-2});

H = monthly average daily global radiation on a horizontal surface ($MJm^{-2}\,day^{-1}$);

H_0 = monthly average daily extraterrestrial radiation on a horizontal surface;

S = monthly average daily number of hours of bright sunshine;

S_o = monthly average daily maximum number of hours of possible sunshine given as;

$$(S_o = \frac{2}{15}\,w_s); \qquad (5)$$

a, b= the regression constants to be determined and can be obtained from the relationship given as (Tiwari and Sangeeta, 1977):

$$a = -0.110 + 0.235\cos ø + 0.323\,(S/S_0) \qquad (6)$$

$$b = 1.449 - 0.553\cos ø - 0.694(S/S_0) \qquad (7)$$

Page presented a modified form of Angstrom-Prescott model with coefficient which he claimed to be applicable anywhere in the world

$$\overline{H}[(0.24 + 0.48)(S_o)]H_o \qquad (8)$$

The root mean square error (RMSE) and mean bias Error (MBE) were used to evaluate the variation and the error between estimated global solar radiation and measured global solar radiation. The expression is stated by EL-Sebail and Trabea, (2005) as;

$$RMSE = \left[\frac{\sum(\overline{H}i,cal - Hi\;measured)2}{n}\right]^{1/2}$$

$$MBE = \left[\frac{\sum(\overline{H}i,cal - Hi,measured)2}{n}\right]^{1/2}$$

V. RESULTS AND DISCUSSION

Table 1 shows the value of extraterrestrial solar radiation (H_o) for each months and the corresponding mean Monthly global solar radiation for Anyigba Kogi State calculated for the various months from January to December.

Month	$\overline{H}_o$	S_o	H_i Calculated	H_i Measured	Error	Error^2
January	38.7524	0.4048	16.7035	16.402	-0.3015	0.0909
February	38.4415	0.4082	18.08151	19.4216	1.34009	1.7958

March	37.9021	0.4097	19.2863	20.9286	1.6423	2.6971
April	37.0546	0.4494	21.0748	22.3609	1.2861	1.6540
May	36.7062	0.3081	16.7460	20.8980	4.152	17.2391
June	36.3773	0.2664	15.1306	16.1654	1.0348	1.0708
July	36.6767	0.2286	14.3769	15.7878	1.4109	1.9906
August	36.6915	0.1388	12.3134	13.6800	1.3666	0.5009
September	37.2336	0.1495	12.5359	20.5848	8.0489	64.7847
October	37.8613	0.2958	15.5665	`17.2066	1.6401	2.6899
November	38.4270	0.4033	16.9097	17.5666	0.6569	0.4315
December	38.7470	0.4235	16.6763	16.2436	-0.4327	0.1872

The root mean square error (RMSE) is calculated for the measured and calculated solar radiation below as:

$$RMSE = \left[\frac{\sum(\bar{H}i,cal - Hi\ measured)2}{n}\right]^{1/2} = \quad RMSE = \left[\frac{([209.77831 - 217.459]2)}{12}\right]^{1/2} = \left[\frac{0.622295}{12}\right]$$

The mean bias error is calculated as follows:

$$MBE = \left[\frac{\sum(\bar{H}i,cal - Hi,measured)2}{n}\right]^{1/2} = \quad MBE = \left[\frac{([209.77831 - 217.459]2)}{5}\right] = \left[\frac{-7.46759}{5}\right]$$

Table 2: Shows the meteorological Parameters for Anyigba, using data between 2011-2016

Month	n (hours)	N (hours)	$\frac{n}{N}$	H_o MJ/m^2/day)	Clearness index KT=Hi/H_o
January	4.7	11.6105	2.4703	38.7524	0.4310
February	4.8	11.7578	2.4495	38.4415	0.5012
March	4.9	11.9578	2.4403	37.9021	0.5088
April	5.5	12.2360	2.2247	37.0546	0.5687
May	3.8	12.3306	3.2448	36.7062	0.4562
June	3.2	12.0088	3.7527	36.3773	0.4159
July	2.8	12.2452	4.3732	36.6767	0.3920
August	1.7	12.2391	7.1994	36.6915	0.3356
September	1.8	12.0386	6.6881	37.2336	0.3367
October	3.5	11.8309	3.3802	37.8613	0.4111
November	4.7	11.6527	2h.4792	38.4270	0.4400
December	4.9	11.5682	2.3608	38.7470	0.4303

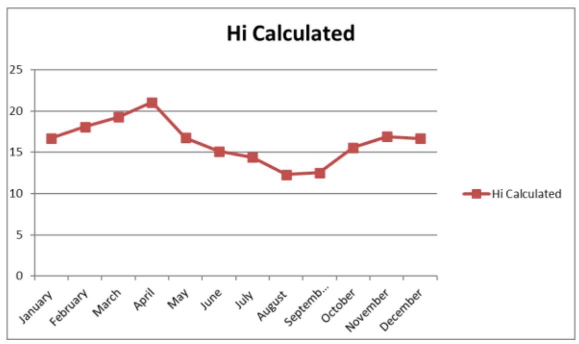

Figure1: The graph of Hi calculated against the various months from January to December

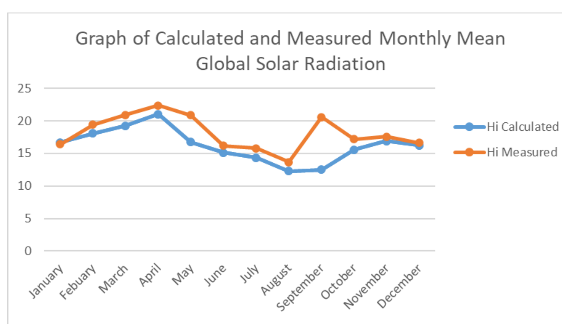

Figure 2: Graph of Hi calculated and Hi measured against the months

VI. DISCUSSION

From the table1, it can see that the Calculated and Measured monthly mean global solar radiation were measured for each of the months and April showed the highest calculated global solar radiation, while August showed the lowest calculated and measured mean.

The relationship between the estimated global solar radiation and the Extraterrestrial solar radiation was shown by the values of the clearness index (KT) calculated using the formula $KT=H_i/H_o$. It can be seen that the month of August which showed the lowest global solar radiation corresponds with the value of the lowest clear sky index, this is as a result of the cloudy weather in the raining season

Figure 1 shows the graph of Hi measured against Hi calculated where the graph shows the agreement between the measured and calculated global solar radiation. Figure 2 shows the graph of Clearness index against months where the graph shows the corresponding behavior of the calculated solar radiation with the clearness of the sky. Also, the graph shows that April has the highest clearness index while August has the lowest clearness index.

CONCLUSION

The result shows a clear agreement between the estimated and calculated global solar radiation with an MBE and RMSE of $-1.4935MJm^{-2}$ and $0.0733MJm^{-2}$ respectively. The MBE and RMSE are within acceptable range and show that Angstrom-Page model is suitable for the estimation of average monthly global solar radiation in Anyigba. The negative sign on the MBE indicates a slight underestimation of the model by $1.4935MJm^{-2}$. The average monthly solar radiation for Anyigba was found to be $16.28345\ MJm^{-2}$.

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