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Theoretical and Artificial Neural Network Computation and Analysis of Global Solar Radiation at Enugu with Atmospheric Parameter

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ABTRACT

Records of measured sunshine hour's data for a period of seventeen years (1991-2007) at Enugu 7.550N, 6.470E and 141.50m within the south-east zone of Nigeria were used to compute the global solar radiation of the same location with theoretical and artificial neural network models. The first part of the results (ie January to May) has similar values with the third part (October to December). This indicate that weather conditions of the location of study is of two periods, rainy and dry seasons. The values of the results also shows that global solar radiation is directly proportional to sunshine hours both for measured, theoretical and artificial neural network computations. Again Correlation of the two models show high performance of neural network over theoretical computation, as the neural network coefficent of determination R2 = 0.96 while coefficent of determination of theoretical computation is R2 = 0.91 respectively. The above result shows that the two models has the ability of computing global solar radiation with sunshine hours, but the artificial neural network computation is more accurate.

Keywords: Atmospheric parameters, theoretical, neural network, Global solar radiation and sunshine hours.

INTRODUCTION

Atmospheric parameters and energy plays an important role in determining the conditions in which living matter can exist and continuous steering power for social, economic, and technological prospective development in Nigeria. The condition of the atmosphere is dictated by the sun and is very dynamic both in space and time scales. The resulting solar interactions on the atmosphere leads to changes in weather as well as the so called climate change.

Renewable energy is considered as the key source for the future, as it is the vital and essential ingredient to human activities of all kind, and can only be acquired through measurement or prediction (Ibeh et al, 2012). Due to the high cost of solar radiation measuring devices, efforts are made to develop various models as alternative ways for the prediction of solar radiation at any location of interest.

It is pertinent to note that many researchers who have done similar work (estimation of global solar radiation) in different locations concentrated on one model, either with artificial neural network or in most cases with empirical model of different modeling. But in this study the theoretical and artificial neural network computations were employed to compute solar radiation with sunshine hours.

DATE SOURCE

The monthly average daily data for the sunshine duration were obtained from the monthly meteorological observations at the Nigeria Meteorological Agency, Oshodi, Lagos, Nigeria and the solar radiation were obtained from Renewable Energy for Rural Industrialization and Development in Nigeria and the duration is from 1991 to 2007. The geographical location of the station is presented in table 1.

Table 1: Geographical location of the station

Station	latitude	longitude	Attitude (m)
Enugu	7.55^0N	6.47^0E	141.50

Artificial neural network (ANN) computation

The basis of the ANN model used is of neuron structure as shown in figure 1:

In other to compute the global solar radiation, 3-2-1 multilayer peceptron (MLP) neural networks were used, which includes the input layer, a linear output layer and a sigmoid hidden function. From Fig. 1 we have that weighed sum of the inputs. The weighed sum of the inputs

$$v_k = \sum_{j=1}^{N} x_j \, w_{kj} + b_k \text{ --- (1)}$$

is calculated at kth hidden node.

w_{kj} is the weight on connection from the jth to the kth node; x_j is an input data from input node; N is the total number of input (N = 12); and b_k denotes a bias on the kth hidden node.

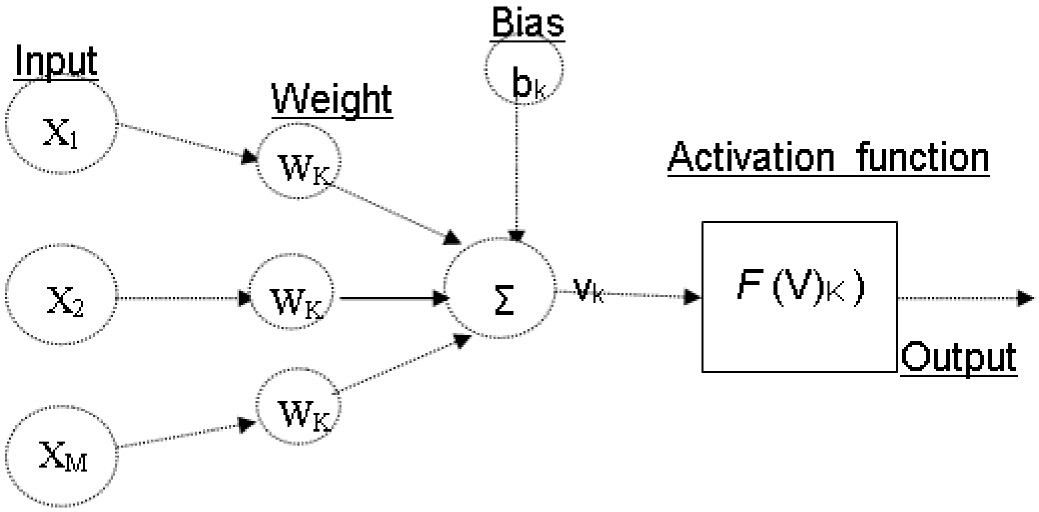

Figure 1: Mathematical Structure of ANN Computation

Each hidden node then uses a sigmoid transfer function to generate an output

$$z_k = [\ 1 + e^{(-v_k)}\ ]^{-1} = f(v_k) \text{ --- (2)}$$

between -1 and 1.

We then set the output from each of the hidden nodes, along with the bias b_0 on the output node, to the output node and again calculate a weighted sum,

$$y_k = \sum_{k=1}^{N} v_k \, z_k + b_k \text{ --(3)}$$

where N is the total number of hidden nodes; and v_k is the weight from the kth hidden node to the sigmoid transfer function of the output node.

Theoretical computation

The empirical model used is the model proposed for estimation of monthly mean daily global solar radiation on a horizontal surface H_s (MJM^2day^1) using sunshine duration on data by Angstrom (1924) and put in a convenience form by Prescott (1940)

$$\frac{H}{Ho} = a + b\frac{n}{N} \quad \text{-------------------------------------- (4)}$$

Where a and b are regression constants

$$H/H_0 = a + b\left(\frac{n}{N}\right) + c\left(\frac{n}{N}\right)^2 \quad \text{-- (5)}$$

$$\frac{H}{Ho} = \text{clearness index}$$

H is the measured monthly mean daily global solar radiation, n is the monthly mean daily bright sunshine hours, N is the maximum possible monthly mean daily sunshine hours,

$$\frac{n}{N} = \text{fraction of sunshine hours} \quad \text{-- (6)}$$

H is the monthly mean extraterrestrial solar radiation on horizontal surface.

The mean values of the extraterrestrial solar radiation can be calculated by taking the average of each month, i.e.

$$H_0 = \frac{\text{total radiation for the month}}{\text{number of days in the month}} \quad \text{--- --------- (7)}$$

The extraterrestrial solar radiation on horizontal surface was calculated using the expression given by Igbal (1983) as;

$$\bar{H}_o = \frac{24}{\pi} I_{sc} E_o \left(\frac{\pi}{180}\ \omega_s \sin\emptyset \sin\delta + \cos\emptyset \cos\delta \ \sin\omega_s\right) ----(8)$$

Where I_{sc} = solar constant

$E_o = Eccentricity\ correlation\ factor$

$\emptyset = latitude$

$\delta =$ Solar declination

$\omega_s =$ Hour angle, N = characteristic day number.

$$I_{sc} = \frac{1367\ X\ 3600}{1000000}\ (MJM^{-2}h^{-1}) ----------------(9)$$

$$E_O = 1 + 0.033\ COS\left(\frac{360N}{365}\right) -------------- -- (10)$$

$$\delta = 23.45\ sin\left[360\ \frac{(N+284)}{365}\right] -------------- - (11)$$

$$w_s = \cos^{-1}(-tan\emptyset\ tan\,\delta) ---------------(12)$$

$$\bar{N} = \frac{2}{15} \cos^{-1}(-\tan\emptyset\tan\delta) \; - - - - - - - - - - - - - - (13)$$

Where $\bar{N}$ = Day length, all other symbols retain their meanings.

RESULTS AND DISCCUSION

According to El-Sebaii, *et al*, 2010 and was confirmed in this work, second and third order correlations do not improve the accuracy of estimation of global solar radiation, therefore, equation (5) computation results were not shown.

A close examination of Table 2 shows that the maximum values of the monthly mean daily sunshine hours and the monthly mean daily global radiation on a horizontal surface are 7.50 hours and 16.51 MJM^{2} day^{1} respectively and they occur in the month of November. This value is within what is expected of a tropical site (Exell, 2000) and (Okogbue and Adedokun, 2005). The month of occurrence is expected because of the high intensity of solar radiation at the period before proceed of harmattern season at the location which normally start by December.

Again, the minimum values of the monthly mean daily sunshine hours and monthly mean daily global radiation on a horizontal surface are 3.78 hours and 10. 80MJM^{-2} day^{-1} respectively and they occur in the month of August. This value is what is expected of a tropical site. (Excell, 2000). The month they occur is also expected. This is the month is characterized by heavy rain falls.

It is important to note that the values of global solar radiation and sunshine from January to May, the values are high, which show close and dry weather condition. The values reduced from June to September, indicating close, wet weather condition and heavy rainfall, and the values also increase from October to December indicating close and dry weather condition. The values indicate the rate of solar radiation from the sun to the earth. The low and high values occur at the expected month.

From Table 2 and Figure 2, it can be deduce that global solar radiation is directly proportional to sunshine hours. Increase in global solar radiation will increase sunshine hours, vase versa. The values from Table 2 also show that global solar radiation can be computed with both neural network and theoretical computation using sunshine hours.

Table 2: comparison between the measured, theoretical and artificial neural network computations of solar radiation with sunshine hours

Month	H(MJM^2day^1) (Measured)	H(MJM^2day^1) (theoretical)	H(MJM^2day^1) (neural network)	n (hours) (sunshine)
Jan	14.25	15.35	14.45	6.35
Feb	15.65	16.01	15.65	6.55
Mar	14.77	15.32	14.80	5.99
Apr	14.27	15.32	14.35	6.45
May	14.85	14.39	14.80	6.49
Jun	13.61	12.49	12.98	5.35
Jul	11.65	11.35	11.70	3.86
Aug	10.80	11.52	10.85	3.78
Sept	12.26	12.98	13.26	4.45
Oct	15.18	15.44	15.83	5.94
Nov	16.51	16.86	16.71	7.50
Dec	15.42	15.88	15.52	6.93

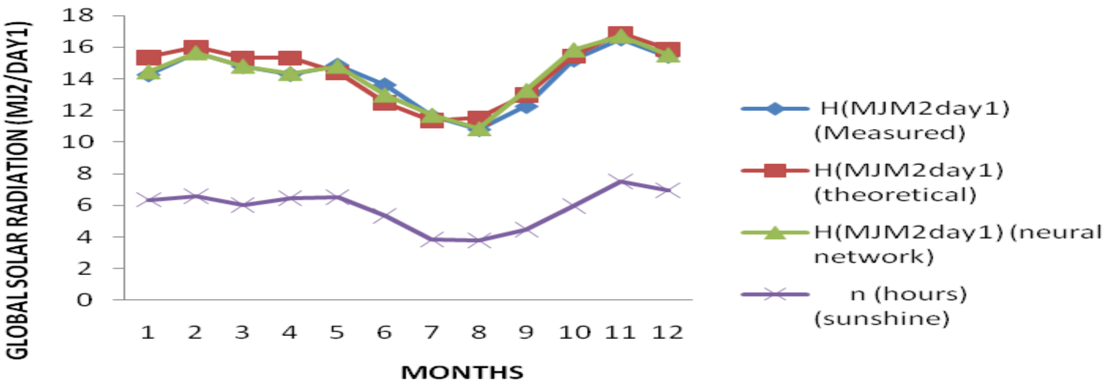

FIG. 2: GRAPH OF THE MODELS COMPUTATIONS

CONCLUSION

From Table 2 the result is divided into three parts. The first part (ie January to May) has similar values with the third part (October to December). This indicate that weather condition of the location of interest is of two periods, rainy and dry seasons. The results shows that the values of global solar radiation is directly proportional to sunshine hours both for measured, theoretical and artificial neural network computations. Correlation of the two models also show high performance of neural network over theoretical computation, as the neural network coefficent of determination R2 = 0.96 while coefficent of determination of theoretical computation R2 = 0.91 respectively. The above result show that the two models has the ability of computing global solar radiation with sunshine hours, but the artificial neural network computation is more accurate.

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