Application of Artificial Neural Network for Estimation of Annual Global Solar Radiation of Warri, Nigeria with Relative Humidity.

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ABSTRACT

The prediction of global solar radiation at Warri, Nigeria (Latitude 5^{o} N, Longitude 5^{o}E) was carried out in this study. The global solar radiation was measured for seventeen years (1991 to 2007) using a pyranometer recorder. The annual mean values were determined. The artificial neural network model was then used to estimate the global solar radiation based on the available climatic parameters of relative humidity. From the results obtained, the values of the measured global solar radiation and prediction from artificial neural network have a close agreement and have been suggested to be utilized very efficiently in the prediction of the performance of global solar radiation for Warri and its environs. This method was employed since the installation of pyranometer is a very costly exercise. The mean bias error, root mean square error and mean percentage error were also used to validate the results from the model prediction and it also confirmed the strong capacity of the model in accurate prediction.

(Keywords: ANN, artificial neural network, relative humidity, error, global solar radiation)

INTRODUCTION

Weather forecasting is the application of science and technology to predict the state of the atmosphere for a future time and a given location (Exell, 2000). 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.

Weather occurs because our atmosphere is in constant motion. It changes every season because of the Earth's tilt when it revolves around the Sun. Some determining factors of weather are temperature, precipitation, fronts, wind, relative humidity, clouds, hurricanes, tornadoes, thunderstorms, etc.

The need for accurate weather prediction is apparent when considering the benefits that it has. These predictions may not stop a tornado, hurricane, or flood, but they can help us prepare for one. Great progress has been made in the science of meteorology. Meteorologists use different methods for weather prediction. Augustine and Nnabuchi (2009), correlated between sunshine hours and global solar radiation in Warri, Nigeria.

This work is aimed at using an artificial neural network (ANN) to predict the global solar radiation of Warri, Nigeria based on the available climatic parameters of relative humidity, measured global solar radiation. This is to ascertain the estimating capacity of ANN in the estimation of global solar radiation of Warri with relative humidity. The accuracy of the estimation was checked with some statistical techniques. Again, the correlation of the results will also be carried out.

Relative humidity is the ratio between the actual vapor content of the air and the vapor content of air at the same temperature saturated with water vapor (Liou, 1980). If the temperature of air rises and no change occurs in its vapor content, then the absolute humidity remains the same, but the relative humidity is lowered. A fall in temperature increases the relative humidity.

ARTIFICIAL NEURAL NETWORK

A neural network is a massively parallel distributed processor made up of simple processing units that have a natural propensity for storing experiential knowledge and making it available (Redmond, 2008). Artificial Neural Network (ANN) is a type of Artificial Intelligence technique that mimics the behavior of the human brain. ANNs have ability to model linear and non-linear systems without the need to make assumptions implicitly as in most traditional statistical approaches, applied in various aspects of science and engineering (Ibeh, et al., 2012).

The network usually consists of an input layer, some hidden layers and an output layer. In its simple form, each single neuron is connected to other neurons of a previous layer through adaptable synaptic weights. Knowledge is stored as a set of connection weights. During training process the connection weights are modified in certain way by using a suitable learning method. The network uses a learning mode, in which an input is presented to the network along with the desired output and the weights are adjusted so that the network attempts to produce the desired output (Redmond, 2008). Therefore, the weights, after training contain meaningful information.

DATA AND METHOD OF ANALYSIS

The annual mean daily data for relative humidity were collected from the Nigerian Meteorological Agency, Federal Ministry of Aviation, Oshodi, Lagos, Nigeria. The global solar radiation data were collected courtesy of Renewable Energy for Rural Industrialization and Development in Nigeria. The data obtained covered a period of seventeen years (1991 – 2007) for Warri, Nigeria (Latitude 5^{o} N, Longitude 5^{o}E.).

The monthly mean data of relative humidity and global solar radiation were processed to annual mean in preparation for the estimation of the global solar radiation of Warri as shown in Table 1.

These neurons act like parallel processing units. An artificial neuron is a unit that performs a simple mathematical operation on its inputs and imitates the functions of biological neurons and their unique process of learning (Ibeh and Agbo, 2012).

The weighed sum of the inputs is calculated at k^{th} hidden node:

$$v_k = \sum_{J=0}^{N} X_j W_{kj} + b_k \qquad \textbf{(1)}$$

W_{kj} is the weight on connection from the j^{th} to the k^{th} node; X_j is an input data from input node; N is the total number of input (N=17); and b_k denotes a bias on the k^{th} hidden node.

Each hidden node then uses a sigmoid transfer function to generate an output between -1 and 1:

$$Z_k = [\,1 + e^{(-v_k)}]^{-1} \qquad \textbf{(2)}$$

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 calculated a weighted sum:

$$y_k = \sum_{k=1}^{N} V_k Z_k + b_k \qquad \textbf{(3)}$$

Where N is the total number of hidden nodes; and v_k is the weight from the k^{th} hidden node to the sigmoid transfer function of the output node.

RESULTS AND DISCUSSIONS

The measured global solar radiation, relative humidity of Warri used in this work, as well as the results from the ANN estimation is shown in Table 1.

Close observation of Table. 1 shows that the highest value of solar radiation occurs in 1993 and the lowest value occurs in 1991, respectively. This indicates that 1993 has high radiation from the sun compared to other years. In the table, it is also show that 1991, 1992, and 2005 to 2007 has a close range, which indicates that in these years at Warri and its environ has almost the same solar radiation from the sun.

The effect of solar radiation of these years will also be in close range. Close examination of Figure 1 further show that measured and ANN model prediction of solar radiation of Warri is in close agreement. Thus, ANN model has been suggested for the prediction of global solar radiation for Warri and its environs.

Table 1: Annual Mean Meteorological Global Solar Radiation, Relative Humidity, and Annual ANN Prediction of Solar Radiation of Warri from 1991 to 2007.

Years	R	$\frac{R}{100}$	$\bar{\bar{H}}_M$ MJm^{-2}day^{-1}	$\bar{\bar{H}}_{ANN\ P}$ MJm^{-2} day^{-1}
1991	73.00	0.73	16.14635	16.54
1992	72.73	0.73	16.67667	16.05
1993	70.73	0.71	20.77718	19.48
1994	69.91	0.70	20.23739	19.29
1995	73.11	0.74	19.38509	18.82
1996	71.35	0.72	19.21463	19.80
1997	70.35	0.71	19.27145	19.37
1998	69.91	0.70	19.76389	19.29
1999	72.27	0.72	18.88318	18.65
2000	74.64	0.75	19.84912	18.99
2001	72.46	0.72	17.11229	17.88
2002	71.73	0.72	20.44573	20.12
2003	74.46	0.74	18.48544	18.89
2004	72.82	0.73	20.21845	20.11
2005	74.40	0.74	17.09335	16.54
2006	75.91	0.76	16.93236	16.05
2007	72.91	0.73	17.47215	18.48

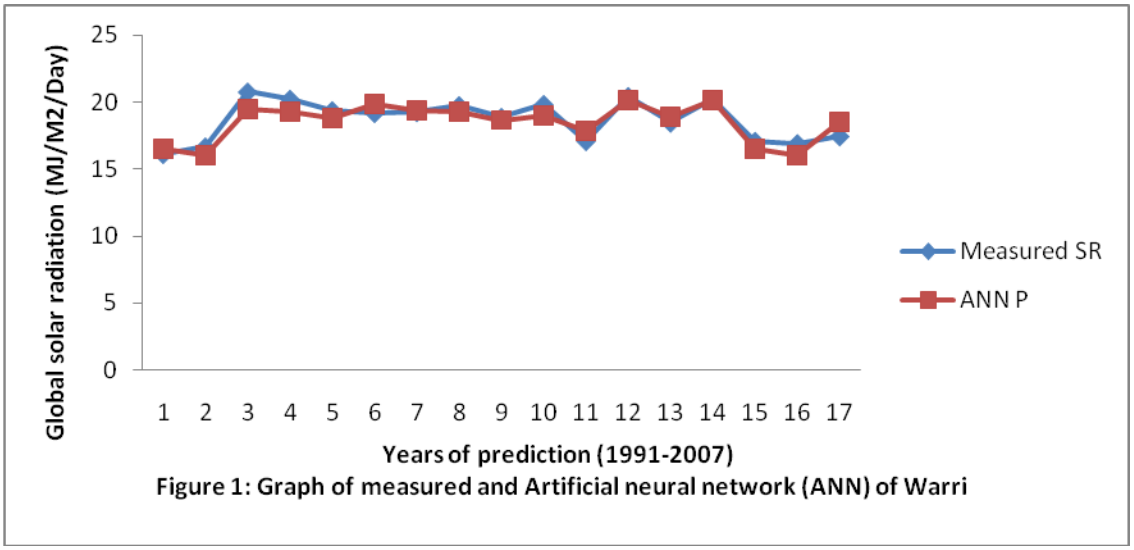

Figure 1: Graph of measured and Artificial neural network (ANN) of Warri

The values of mean bias error, root mean square error and mean percentage error are -0.010502, 0.128895, and 0.09170, respectively. It is important to note from the result that the mean percentage error from the ANN model is less than 1 %.

CONCLUSION

The results of this research clearly indicates the importance of using ANN approaches for predicting the annual global solar radiation on horizontal surfaces reaching the Earth at different locations in Warri, Nigeria.

From the above results, the maximum values of annual global solar radiation appears in 1993, 194, 2002, 2004 with 20.78 $MJm^{-2}day^{-1}$, 20.24 $MJm^{-2}day^{-1}$, 20.45 $MJm^{-2}day^{-1}$and 20.21 $MJm^{-2}day^{-1}$, respectively, and minimum values occur in 1991, 1992 and 2006 with 16.15 $MJm^{-2}day^{-1}$, 16.68 $MJm^{-2}day^{-1}$, and 16.93 $MJm^{-2}day^{-1}$, respectively. The high value indicates high intensive solar radiation and low values indicates low solar radiation.

From the close relationship that exist between measured and ANN predicted results, it is clear that ANN model is a good model for solar radiation prediction, thus has been suggested for the estimation of global solar radiation of Warri, Nigeria and its environ.

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REFERENCES

1. Augustine, C. and M.N. Nnabuchi. 2009 "Correlation between Sunshine Hours and Global Solar Radiation in Warri, Nigeria". *Pacific Journal of Science and Technology*. 10(2) 574-579.

2. Exell, R.H.B. 2000. *The Intensity of Solar Radiation*. King Mongkut's University of Technology Press: Bangkok, Thailand.

3. Ibeh, G.F, G.A. Agbo, S. Rabia, and A.R. Chikwenze. 2012. "Comparison of Empirical and Artificial Neural Network Models for the Correlation of Monthly Average Global Solar Radiation with Sunshine Hours in Minna, Nigeria " *International J. of Physical Sciences*. 7(8):1162-1165

4. Liou, K.N 1980. *Introduction to Atmospheric Radiation*. Academy Press: New York, NY.

5. Microsoft Corporation. 2008 *Microsoft Encarta 1993-2008*. Microsoft: Redmond, WA.

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