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Application of Artificial Neural Networks for Global Solar Radiation Forecasting With Temperature

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ABSTRACT

In this study, the prediction of global solar radiation at Warri, Nigeria latitude'5.02^{0}N, were carried out with ANN. This method was employed since installation of pyranometer is a very costly and uncommon exercise. From the results obtained, the maximum values of global solar radiation appears in April and December with 15.94 MJm^{-2}day^{-1}, and 15.98 MJm^{-2}day^{-1} respectively during dry season while minimum values of 11.02MJm^{-2}day^{-1},11.30 MJm^{-2}day^{-1}, 12.31MJm^{-2}day^{-1}, 12.91 MJm^{-2}day^{-1}, occurs in February, may, June, July, and August, respectively during wet season. From the close relationship that exist between measured and ANN predicted results in table and figures, it is clear that ANN model is a better model for solar radiation prediction.

Key words: Temperature, solar radiation, neural network, atmosphere, season.

INTRODUCTION

Temperature plays an important role in determining the conditions in which living organisms can exist. Thus, birds and mammals demand a very narrow range of body temperatures for survival and must be protected against extreme heat or cold

It is one of the determining factors of the weather. It varies with altitude from one atmospheric layer to another, and stays constant for about altitude of 10 km. The atmosphere always contains some moisture in the form of water vapor; the maximum amount depends on the temperature. The amount of vapor that will saturate the air increases with a rise in temperature

The temperature of the atmosphere is greatly influenced by both the land and the sea areas. In dry season, for example, the great landmasses of the northern hemisphere are much colder than the oceans at the same latitude, and in rainy season the situation is reversed (5). At low elevations the air temperature is also determined largely by the surface temperature of the earth (5). The periodic temperature changes are due mainly to the sun's radiant heating of the land areas of the earth, which in turn convect heat to the overlying air.

Solar energy travels to Earth through space in discrete packets of energy. Only half of that amount, however, reaches Earth's surface. The atmosphere and clouds absorb or scatter the other half of the incoming sunlight. The amount of light that reaches any particular point on the ground depends on the time of day, the day of the year, the amount of cloud cover, and the latitude at that point.

Knowledge of the solar radiation is essential for many applications, including architectural design, meteorological forecasting, solar energy systems, crop growth models, conversion for electricity, sciences and technology, etc.
The amount of solar radiation reaching the earth can best obtained by installing pyranometer at any site and day to day readings from the instrument give us the data. But because of the unavailability of the instruments in many sites, atmospheric parameters at a particular location are being use to predict the global solar radiation in that location.

In this work, ANN was used to predict the global solar radiation of Warri, Nigeria based on the available climatic parameters of maximum temperature, measured solar radiation and the computed values of the extraterrestrial solar radiation.

MATERIALS AND METHODS

The monthly mean daily data maximum temperatures 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 (5.02^0N, 7.88^0E).

The monthly average data processed in preparation for the prediction are presented in Table 1.

According to Angstrom-Prescott (4), the relationship between clearness index and maximum temperature is

$\frac{\bar{H}_M}{\bar{H}_O}$ = a + b T_M ---------- (1)

$\bar{H}_m$ = measured solar radiation
$\bar{H}_o$ = monthly mean daily extraterrestrial radiation
a and b = regression constants
T_m= maximum temperature

This work was based on Multi Layer Perceptron (MLP) of ANN which trained and tested using past seventeen years (1991-2007) meteorological data. The chosen weather data were divided into three randomly selected groups, the training group, corresponding to 66.7% of the patterns, and the test group, corresponding to 8.3% of patterns; so that the generalization capacity of network could be checked after training phase. Also three random months were selected as holdout data and it corresponds to 25.0%.

The following is an outline of the procedure used in the development of the ANN model:

i) Input and target values were normalized, in the range -1 to 1.
ii) Matrix size of the dataset was defined.
iii) Partition; create training, test and validation sub-datasets.
iv) The MLP neural network was created
v) The MLP neural network was trained
vi) Automatic Architecture selected
vi) Output values generated
vii) Un-normalize the output values.
viii) The performance of the neural network was checked by comparing the output values with measured values.

RESULTS AND DISCUSSION

Table 1: Meteorological Data of Measured and Predicted ANN solar Radiation, and Maximum Temperature of Warri

MONTH	$\bar{H}_M$ (MJm^{-2}day^{-1})	$\bar{H}_o$ (MJm^{-2}day^{-1})	$\bar{K}_T = \bar{H}_m / \bar{H}_0$	T_M o_C	ANN SR (MJm^{-2} day^{-1})
JAN	11.02	34.21	0.3221	33.00	14.41
FEB	12.55	35.06	0.3579	33.68	14.02
MAR	13.76	37.72	0.3648	33.45	14.17
APR	15.94	36.48	0.4369	32.86	14.45
MAY	11.30	36.22	0.3119	31.93	13.93
JUN	12.31	34.13	0.3607	30.53	12.11
JUL	12.91	35.81	0.3605	28.77	12.99
AUG	12.19	35.05	0.3478	29.99	12.21
SEPT	13.55	36.26	0.3737	31.28	12.80
OCT	14.56	36.68	0.3969	32.28	14.33
NOV	13.91	34.58	0.4023	33.74	13.98
DEC	15.98	32.49	0.4918	32.66	14.47

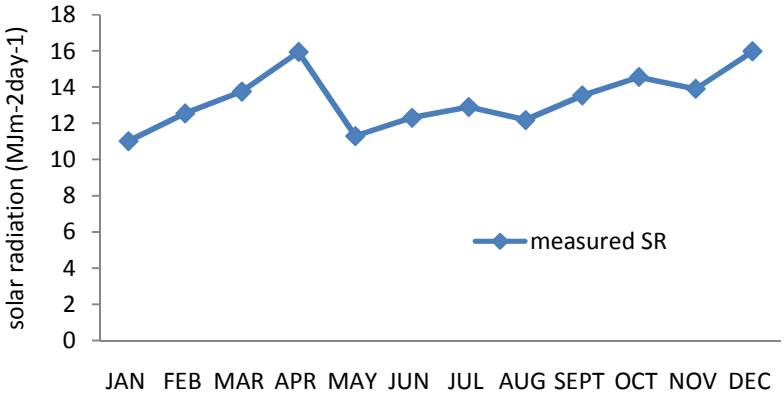

Figure 1: Graph of measured Solar radiation

Table 1 shows the calculated values of measured monthly mean daily sunshine hour's $\bar{n}$ possible fraction of sunshine $\frac{\bar{n}}{\bar{N}}$, the monthly mean daily sunshine hours $\bar{N}$and monthly mean daily global solar radiation on a horizontal surface$\bar{H}_M$, extraterrestrial solar radiation on a horizontal surface$\bar{H}_M$, as well as the clearness index $\bar{K}_T$.

It was observed from table 1 that there were consistent decreases in values of maximum temperature, measured solar radiation, extraterrestrial solar radiation on the horizontal surface as well as the ANN predicted solar radiation from May to September. The low values are attributed to rainy season in Nigeria when temperature is expected to be low. The high value of temperature in December, January, February, explain while the great landmasses of the northern hemisphere are much colder than the oceans at the same latitude, and low value in July confirmed the reversed situation. This indicates that temperature of the atmosphere is greatly influenced by both the land and the sea areas. Figure 1-3 shows the correlation relationship between measured and ANN predicted measured solar radiation. It is important to note that the agreement between the ANN and measured values became stronger from June, and it continues up to December, which indicates that ANN has long term performing capacity and can do better with large data.

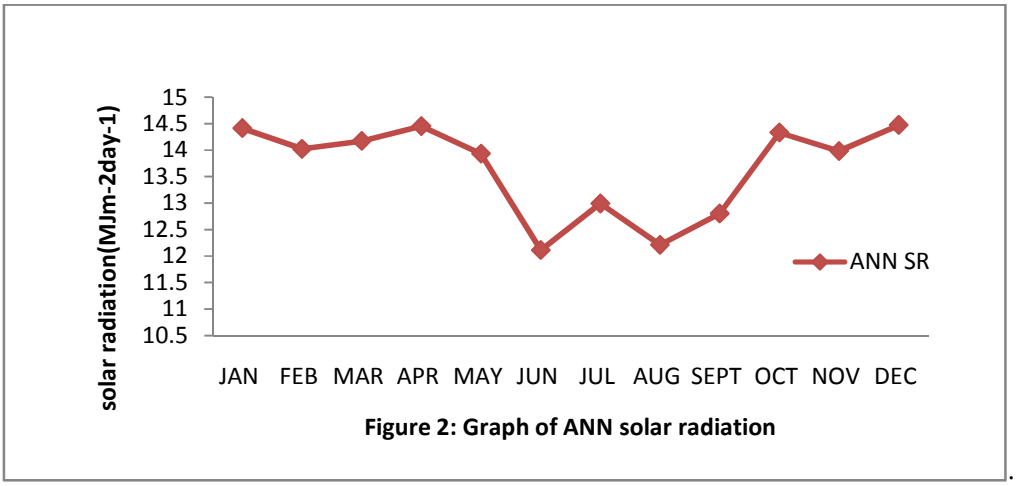

Figure 2: Graph of ANN solar radiation

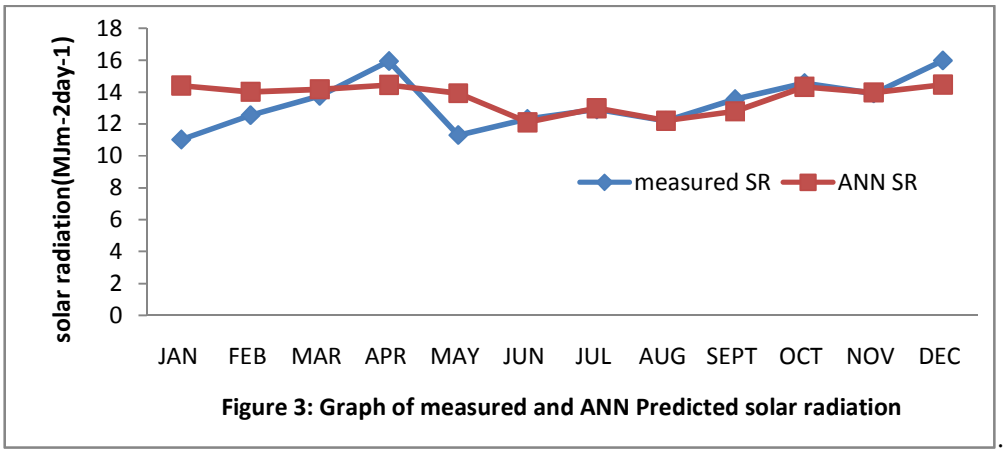

Figure 3: Graph of measured and ANN Predicted solar radiation

The reports of Table 1, as well as Figures 1, shows that the minimum value of global solar radiation is 11.02 $MJm^{-2}day^{-1}$. It occurs in the month of January. This result is expected because the month of January is harmattan period in Nigeria, particularly the southern part of the country.

The high values of solar radiation from table 1 occurs in April and December when most state in southern parst of the country experiences high intensity of sunshine.

CONCLUSION

Energy plays an important role in determining the conditions in which living matter can exist and is continuous steering power for the social, economic and technological prospective development.

Renewable energy is consider as the key source for the future as it is the vital and essential ingredients to human activities of all kind, and can only be acquired through measurement or prediction.

The result of this work, clearly indicate the importance of using ANN approaches for predicting the global solar radiation on horizontal surface reaching the earth at different location in Warri – Nigeria.

From the above results, the maximum values of global solar radiation appears in April and December with 15.94 $MJm^{-2}day^{-1}$, and 15.98

$MJm^{-2}day^{-1}$ respectively and these fell with during dry season while minimum values of 11.02 $MJm^{-2}day^{-1}$, 11.30 MJm-$2day^{-1}$, 12.31$MJm^{-2}day^{-1}$, 12.91 $MJm^{-2}day^{-1}$, occurs in February, May, June, July, and August, respectively during wet season.

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.

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