Application of Artificial Neural Network to Predict Annual Global Solar Radiation for PV System's Sizing in UUM Area, Malaysia.

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ABSTRACT

The knowledge and estimation of global solar radiation are very crucial in application of photovoltaic (PV) solar system at a particular location. Estimation of global solar radiation at University Utara Malaysia (UUM) area, Malaysia, (Latitude 6^0N and longitude 100^0E) was carried out in this study. The artificial neural network model was used to predict the global solar radiation based on the available simple atmospheric parameters of ambient temperature. The statistical analyses were employed to validate the results obtained from the model. It is deduced from the results obtained that the values of the measured global solar radiation and the estimated values from artificial neural network model have a very close agreement and therefore, have been suggested to be utilized very efficiently in the prediction of the performance of global solar radiation for photovoltaic system application in UUM area and its environs. The values of mean bias error, root mean square error and mean percentage error are 0.00062, 0.00812 and -0.813 respectively. This confirmed the strong capacity of using the model to estimate global solar radiation in the study area for photovoltaic system utilization.

Key words: Global solar radiation, Temperature, Artificial neural network, Solar energy, UUM, Malaysia.

1.0 INTRODUCTION

Solar radiation assorted at the earth's surface and in the atmosphere is the initial source of energy causing atmospheric motions. A reliable treatment of atmospheric radiation in numerical models of the atmospheric circulation is required for long-range weather forecasts and for climatologically studies [1]. Solar radiation is a determining factor in studying the natural potential of solar energy as a source of renewable energy. The availability of the solar radiation usage on the earth surface depends on the atmospheric parameters such as temperature, relative humidity, rainfall, cloud wind speed and so on. With the estimated amount of solar radiation reaches the earth's surface, solar energy may therefore be considered as potential energy

source for domestic, industrial and commercial purpose.

However, the knowledge of global solar radiation is essential in the prediction, study and design of economic viability of photovoltaic system which use solar energy. Information on global solar radiation received at any location should be useful not only to the locality where the radiation data is obtained but also for the wider world community [2]. Hence, for the purpose of worldwide marketing, the designers and manufacturers of photovoltaic system components need to know the mean global solar radiation available in different and specific locations.

Measured data is the best form of this knowledge, but due to limited availability of meteorological stations that measure global solar radiation, especially in remote and rural areas where the application of the photovoltaic system is very essential. In these locations where no measured values are available, common application has been used in determining this parameter by appropriate correlations which are empirically established using the measured data. Many empirical models have been applied to estimate solar radiation using available meteorological and climatologically parameters such as ambient temperature [3], relative humidity [4], sunshine hours [5] [6] and cloudiness [7].

Malaysia is a country that has abundant solar energy. The annual average daily solar irradiations for Malaysia have a magnitude of 4.21 – 5.56 $Kwhm^{-2}$ while sunshine duration is more than 2,200 hours per year [8]. Unfortunately for many developing countries like Malaysia, global solar radiation measurements are not easily available due to high cost of equipments as well as maintenance cost. A major solution to this problem is to estimate these parameters using model.

The main objective of the present study is to make use of artificial neural network (ANN) in predicting global solar radiation in the Northern part of Malaysia, particularly in Universiti Utara Malaysia for purpose of designing and installing photovoltaic power generating system. In order to ascertain this prediction, ANN is used to determine the global solar radiation of the area with the aid of ambient temperature which is very simple and easy to measure. ANN is a massively parallel distributed processor made up of simple processing units that has a natural propensity for storing experiential knowledge and making it available [8]. ANN is a type of Artificial Intelligence technique that mimics the behavior of 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 [9]. ANNs are capable of capturing the characteristic of any phenomenon with a very good degree of accuracy. This system often gives best alternative to traditional physical-based models, and excels at uncovering relationships in data. It is also a very powerful estimator which is recommended when the functional form between input-output is known or it is not well understood.

2.0 MATERIALS AND METHODS:

The data used for this study was obtained from the Malaysian Meteorological Department. The data obtained cover a period of eleven years (1999 – 2009) in the area of study (latitude 6°N, longitude 100°E). The monthly average data obtained were converted to annual average data in preparation for the estimation of annual

global solar radiation of the study area as shown in Table I. The study made use of artificial neutron network as the study methodology. An artificial neuron is a unit that performs as a simple mathematical operation on its inputs and imitates the functions of biological neurons and their unique process learning [8]. The weighed sum of the Inputs;

$$A_K = \Sigma_{J=0}^{N} X_j W_{kj} + b_k \quad (1)$$

is calculated at K_{th} hidden node

W_{kj} is the weight on connection from the J_{th} to the Kth node; N is the total number of input (N = 11); b_k is a bias on the K_{th} hidden node

$$BK = [\ 1 + e^{(-AK)}\ ]^{-1} \quad (2)$$

We then set the output from each of the hidden nodes, along with bias b_k to the output node and again calculated a weighted sum; $C_K = \Sigma_{k=1}^{N} A_k B_k + b_k$ [9] (3)

Where N is the total number of hidden nodes, and A_K is the weight from the K_{th} hidden nodes, to the sigmoid transfer function of the output node. The estimated results given by the artificial neural network was then validated using the following errors analysis; mean bias error (MBE), root mean square error (RMSE) and mean percentage error (MPE).

3.0 RESULTS AND DISCUSSION

Table 1 shows the measured ambient temperature, measured global solar radiation (Hm), and the predicted or estimated global solar radiation (Hp) from the artificial neural network model. From the table, it is observed clearly that the highest magnitude of solar radiation was received on the earth surface in the year 2001 and the lowest magnitude of solar radiation was received in the year 2000 at the study area. Also, it is observed from the table that year 2002, 2003, 2005 and 2008 have a close range in the values of solar radiation, this implies that in these years, at the area of study, almost the same magnitude of solar radiation were received on the earth surface from the sun. Hence, the effect of solar radiation characteristic will also be in close range in these years, thus, this could also be attributed to stable climate characteristics in the study area. From this average annual global solar radiation provided for each of the year in the table 1, it is proof and ascertained that the area of study and its environs actually have high potential for the solar energy applications of any solar devices, especially for the photovoltaic solar system to sustain both long term and less expensive power supply compared to conventional power system currently using in the area.

Figure 2 display the variation of the measured values of global solar radiation obtained in the study area and predicted results of global solar radiation by ANN model with number of years. Comparison of the results obtained from the artificial neural network model and measured values of annual global solar radiation are presented graphically in figure 2. From this graphical analysis, it could be deduced that result from artificial neural network model estimation has a closer agreement with the measured values of annual global solar radiation in the study area. Moreso, it is deduced from the graphical analysis in the figure 2, that the results of the differences between the measured values and artificial neutral network model values of global solar radiation for the year 2001, 2002, 2008 and 2009 are approximately equal to zero. While in the other years, the artificial neutral network model gives global solar radiation values that very close range with the measured values of global solar radiation. This indicates and gives confirmation that

predictive value by artificial neutral network model and measured values are of the same values. Hence, the model can serve as a baseline tool that will use in designing and sizing photovoltaic system application UUM area and its environs for both PV installers and users.

Global solar radiation depends upon the location and has many effects on the type and rate of chemical reaction in the atmosphere. It affects the air convection and mixing and thus, the ambient temperature of the day. However, it is observed from figure 3, that the average maximum temperature always recorded in the months of February to April is around 29^0C, while the average minimum temperature recorded is round 27^0C in the months of May to December and January. Generally, the trend of mean ambient temperature variation expected to be similar to all the studied years in the area, since the ambient temperature is the function of the global solar radiation reaching the earth's surface.

Validation of the results estimated by the artificial neural networks model using error analysis gives the values of mean bias error (MBE) as 0.00062, root mean square error (RMSE) as 0.00812 and mean percentage error (MPE) as -0.813. It can be concluded from the errors analysis results that low values of both MBE and RMSE attributes to the good performance of the artificial neural network model. It is also important to note from the results that the value of MPE from the artificial neural network model is less than 1%.

4.0 CONCLUSION

In the absence of global solar radiation data, reliable estimates can be made from easily available atmosphere parameters such as ambient temperature. In this study, using the northern part of Malaysia particularly UUM as a case study, artificial neural network model was used for estimation of global solar radiation using annual ambient temperature covers a period of eleven years (1999-2009). The results obtained from the model were validated using three different error analysis.

The result obtained from this study clearly indicates the importance of using artificial neural network model for estimating the annual global solar radiation on horizontal surface reaching the earth surface. Based on the validation results, it therefore become clear that artificial neural network has better agreement in performance with measured values of global solar radiation in the study. The model is simple and could estimate the global solar radiation with relatively high accuracy. Therefore, it is recommended that artificial neural network model should be used, even when only temperature data are available, for estimation of global solar radiation in the UUM area, Malaysia and other locations with similar solar characteristics. Finally, the model provides a simple and low cost system for estimating solar radiation in the study area. It does not require information from neighboring stations for spatial interpolation and it does not require expensive hardware for data processing.

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Table I: Annual Average Measure Global Solar Radiation, Ambient Temperature and Annual Predicted Global Solar Radiation for UUM Area, Malaysia.

Year	Min Ambient temperature(^{0}C)	Max Ambient temperature(^{0}C)	Average Ambient temperature(^{0}C)	Mean Annual Measured Global solar Radiation, Hm (Kwh/m^2)	Mean Annual Predicted Global solar Radiation, Hp (Kwh/m^2)
1999	23.0	32.0	27.5	5.45	5.69
2000	23.0	31.0	27.0	5.40	5.75
2001	23.0	31.0	27.0	5.66	5.80
2002	24.0	31.0	27.5	4.84	4.90
2003	23.0	32.0	27.5	4.84	5.00
2004	23.0	32.0	27.5	5.20	5.60
2005	24.0	32.0	28.0	4.80	5.10
2006	23.0	31.0	27.0	5.54	5.90
2007	24.0	32.0	28.0	5.30	6.00
2008	23.0	31.0	27.0	4.82	4.90
2009	23.0	31.0	27.0	5.44	5.60

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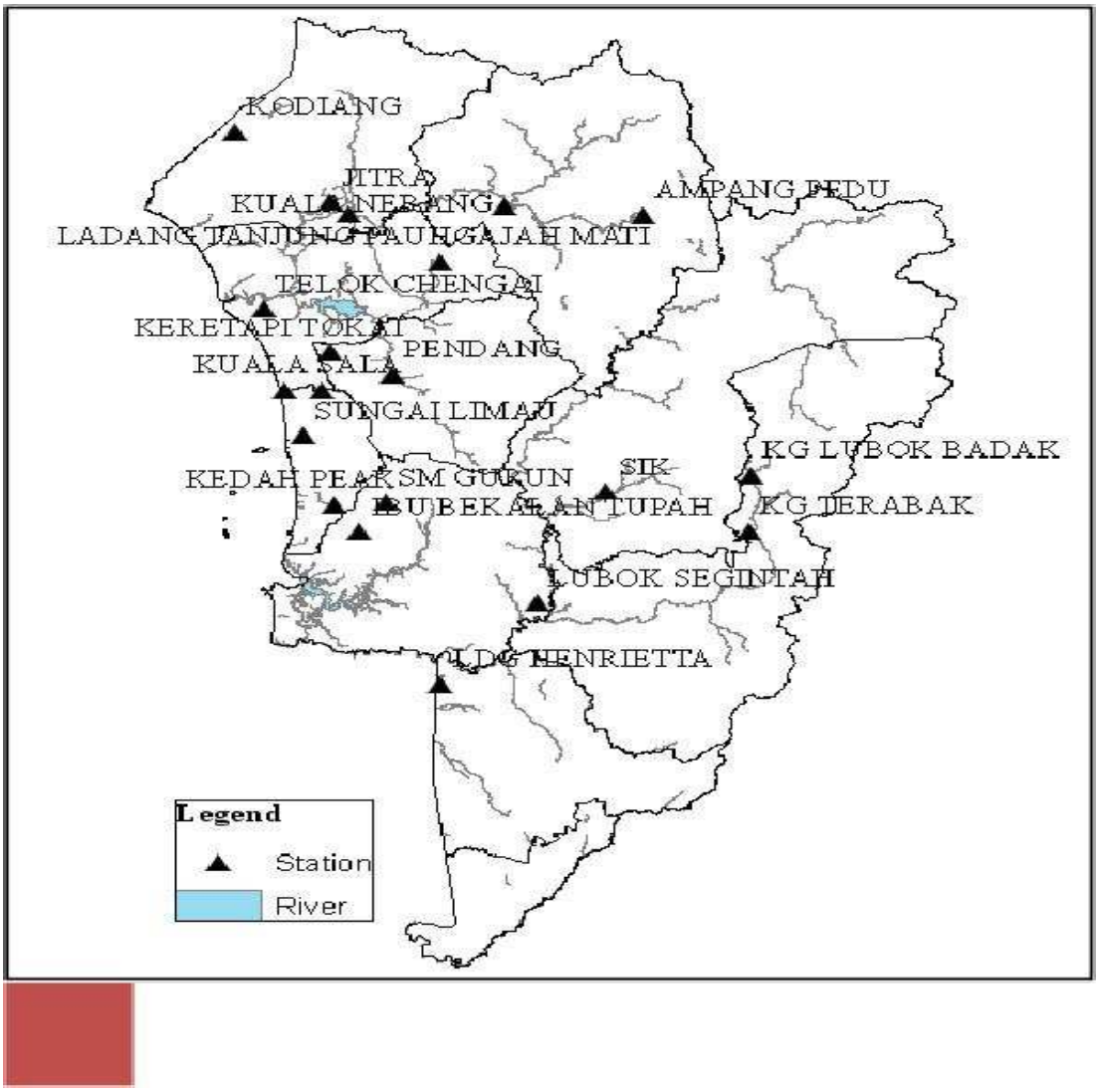

Figure 1: The Map of the Study Area and its Environment.

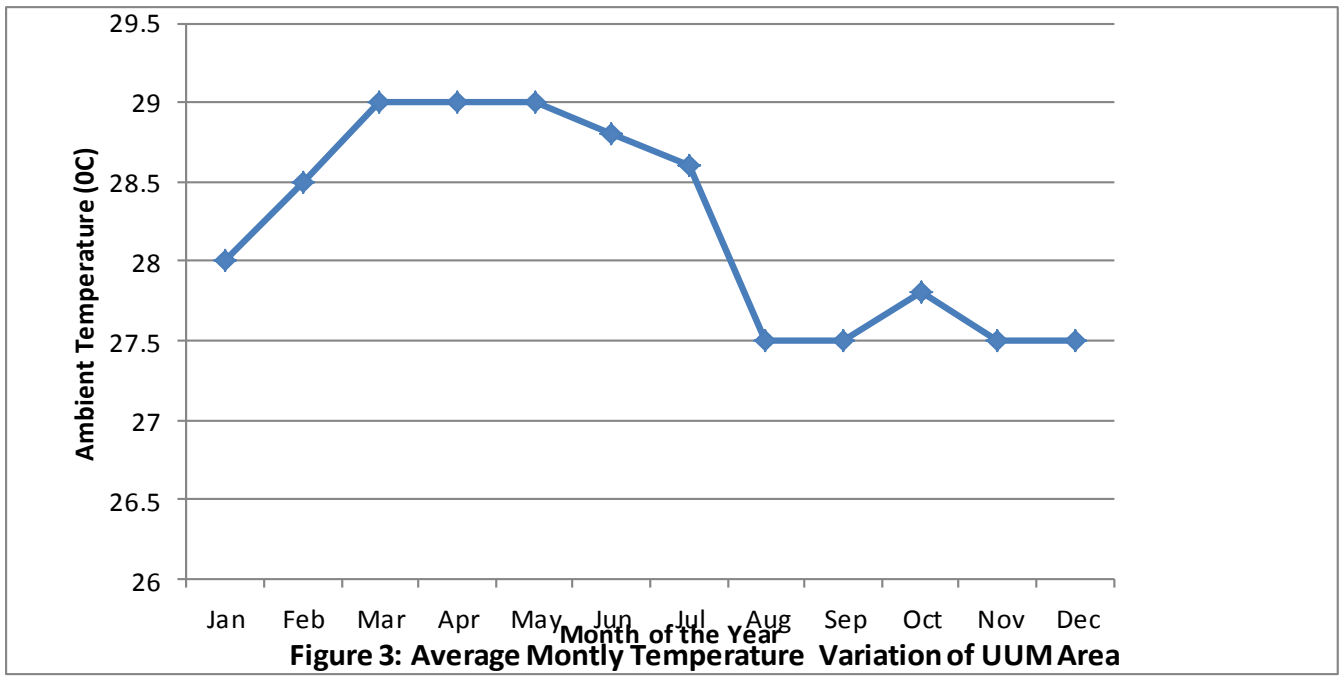

Figure 3: Average Montly Temperature Variation of UUM Area

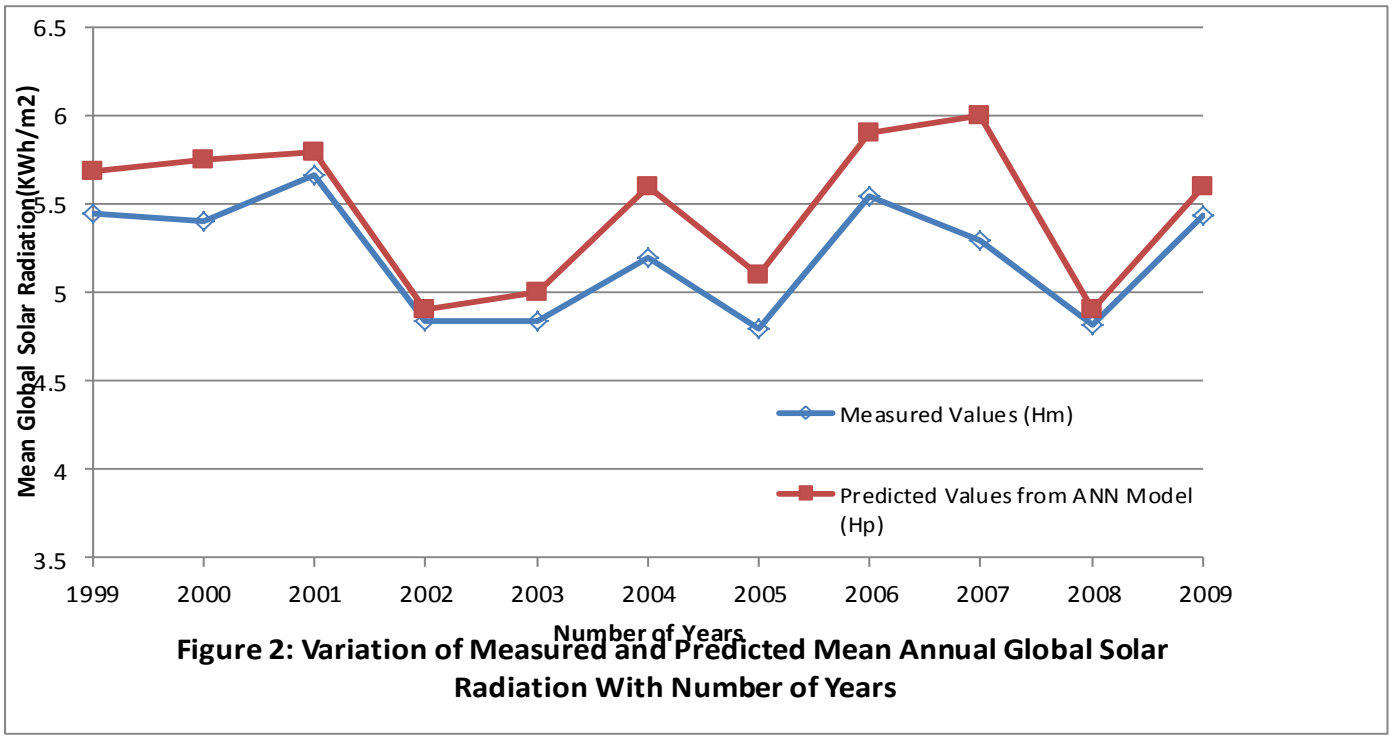

Figure 2: Variation of Measured and Predicted Mean Annual Global Solar Radiation With Number of Years

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