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Estimation Of Solar Radiation By Artificial Networks: East Coast Malaysia

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Abstract

In this paper the solar radiation forecasting in Pekan located in Pahang is presented. The time series utilized are 10 minute solar radiation data obtained directly from the measurements realized in the sites during about one month. In order to do solar radiation forecasting, quick propagation algorithms Artificial Neural Network (ANN) models were developed. Around 1617 data's are taken to train ANN. The effects of temperature, humidity, wind speed, wind chill, pressure and rain on solar radiation are discussed in this paper. The maximum mean absolute percentage error was found to be less than 7.74% and R-squared (R2) values were found to be about 98.9% for the testing stations. However, these values were found to be 5.398% and 97.9 % for the training stations. The trained and tested ANN models show greater accuracy for evaluating the solar radiation. The predicted solar potential values from the ANN are given in the form of table where included the other variables such as temperature, humidity, wind speed, wind chill, pressure and rain. This table is of prime importance for different working disciplines, like scientists, architects, meteorologists and solar engineers, in Malaysia. The predictions from the ANN models could enable scientists to locate and design solar energy systems in Malaysia and determine the best solar technology

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Keywords: Solar radiation, Quick propagation, Artificial Neural Network, Temperature, East coast Malaysia

1. Introduction

Malaysia lies entirely in the equatorial region. The tropical environment has been characterized by heavy rainfall, constantly high temperature and relative humidity. The annual average daily solar irradiations for Malaysia were from 4.21 kWh/m2 to 5.56 kWh/m2. The highest solar radiation was estimated at 6.8

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kWh/m2 in August and November while the lowest was 0.61 kWh/m2 in December. The Northern region and a few places in East Malaysia has the highest potential for solar energy application due to its high solar radiation throughout the year [1]. The scaled quick propagation algorithm and quick propagation coefficient learning algorithm and a logistic sigmoid transfer function were used in the neural network. Weather station data (temperature, humidity, wind speed, wind chill, pressure and rain) are used in the input layer of the network. Solar radiation is in the output layer. The most important theme in this study is to obtain the solar estimation of Pekan by using an ANN. In addition, the best approach with minimum error for each station has also been determined by Neural Network software. Thus, the decision about the quality of each approach (model) may be given using some numeric criterion like R-square and correlation. The predicted solar potential values from the ANN are given in table form. Solar engineers, architects and meteorologists in many application areas of solar energy require a reasonably accurate knowledge of the solar resource availability at any place. So, these maps are of prime importance for these users in Malaysia.

2. ARTICIAL NEURAL NETWORK

ANNs have been successfully employed in solving complex problems in various fields of application, including pattern recognition, identification, classification, speech, vision and control systems. Today, ANNs can be trained to solve problems that are difficult for conventional computers or human beings [2]. The network usually consists of an input layer, some hidden layers and an output layer [3]. The best architecture of network is selected according to its best of training error. Total of eight networks has been tested. Each input is multiplied by a connection weight. In the simplest case, the products and biases are simply summed, then transformed through a transfer function to generate a result and, finally, obtain an output. Networks with biases can represent relationships between inputs and outputs more easily than networks without biases. A transfer function, consisting generally of algebraic equations, is linear or nonlinear [4, 5, 6]. In the current application, the objective is to use the supervised network with quick propagation algorithms to predict solar radiation. The components of the input pattern consist of temperature, humidity, wind speed, wind chill, pressure and rain, whereas the components of the output pattern represent the responses from sensors. The nodes in the hidden layer are necessary to implement the nonlinear mapping between the input and output patterns. Fig. 1 shows the best 5 network according to their absolute error. It shows that architecture 8-20-1 produces the best R-squared and train error.

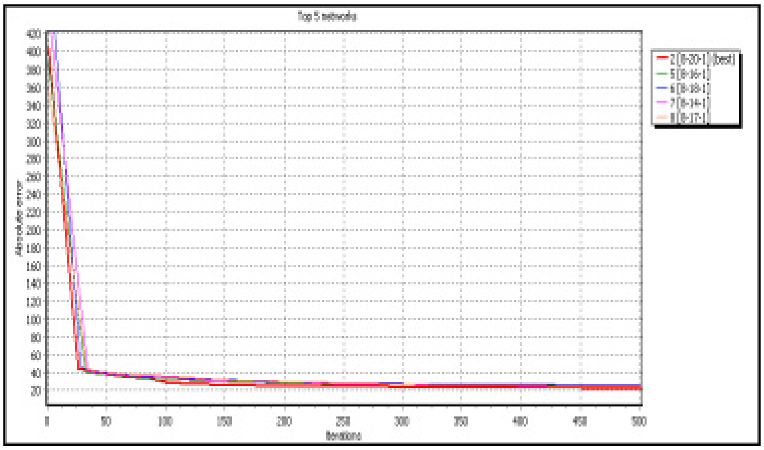


Fig.1: 5 network according to their absolute error.

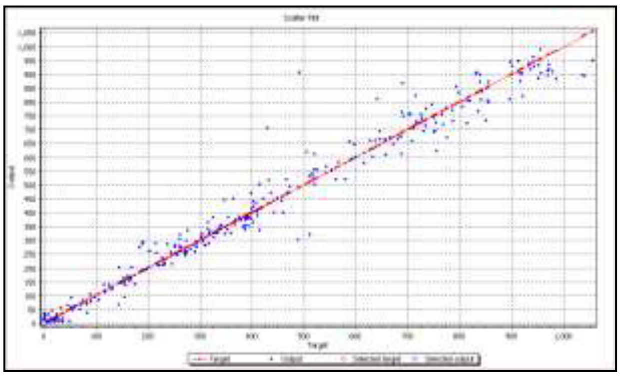
3. Experimental set-up

University Malaysia Pahang has been carrying out research on the use of solar energy and measuring solar energy potential in Pekan and monitoring solar radiation and solar energy over a 1-year period. The tallest building in the university was selected to install the wind tower; this will eliminate any blockage by other buildings. Structure is designed with 6 m height and the basement of structure is screwed with the building cement base. At the top of the structure, a wireless sensor (300 m line of sight) is installed, which transmits the reading to a Weatherlink data logger located inside a room. The sensor is powered by solar energy, and a lithium battery provides back up at night and during cloud weather. Temperature and humidity sensors are located inside the radiation shield. The shield protects the sensors from solar radiation and other sources of radiated and reflected heat. It also included with rain collector which meets the guidelines of the World Meteorological Organazation, and reads the rainfall amount in 0.01 to 0.2 mm increments. The data collected every 10 min and then average it for one day. The latitude of the point where the wind tower fixed (3° 32' 17”) is measured with a GPRS system.

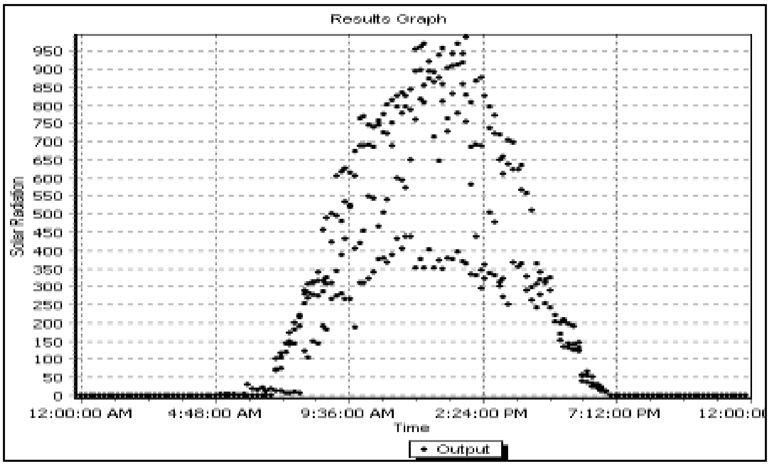
4. Result and discussion

The average solar radiation indicated that is around 982 W/m^2 and solar energy around 400 Ly. The highest solar radiation reached up to 1200 W/m^2. Apart from that, a few areas in East Malaysia also shows the potential in solar energy application as these areas receive from an average to very high solar radiation especially between May until November [1]. The lowest solar radiation estimated for East

Malaysia is recorded in December until January. Although the tested period seems short, but it has appeared that the developed artificial neural network model with one hidden layers based on the standard quick propagation algorithm, using logistic sigmoid function in hidden and output layers, respectively as activation functions, resulted as a very efficient model to estimate the hourly total and diffuse solar radiation measured on the horizontal surface at Universiti Malaysia Pahang (Malaysia). The comparison between estimated and observed values during training and testing phases is depicted in Fig. 2(a) for hourly total solar radiation on a horizontal surface, respectively. The statistical results by the determination coefficient R^2, confirming a good fit of the data predictions of hourly total solar irradiation obtained were correlated well with the observed values, giving a correlation coefficient of 0.9898 and 0.9947 in training and testing phases, respectively. The estimator namely a coefficient of determination (R^2), which was used to indicate how closely the predicted data agreed with the observed data, have lower values in training and testing phases compared with values when estimating solar radiation as reported. Coefficients of determination (R^2) were found to be 0.9794 and 0.9892 for the solar radiation on the horizontal surface during training and testing phases, respectively. These results show that approximately 98.92% of the variation in the dependent variables (output parameters) can be explained by the independent variables (input parameters) selected. However, the drawback of the neural approach is that no deep understanding on the physical phenomena is gained by using a neural network, since it resembles the behavior of a black-box method [7]. The data are apparent that the predicted data agree quite well with from 06.30 am until 18.40 p.m as shown in Fig. 2(b). It shows that high temperature and wind chill produce higher solar radiation, whereas low humidity produces high solar radiation. These trends agree with Hamrouni *et al.* [8] and Kassim *et al.* [9] where the solar radiation increase with temperature. Meanwhile Omubo-Pepple *et al.* [10] found that the optimum solar power achieved with low humidity and high temperature.



(a)



(b)

Fig.2 : (a) Estimated and observed values during training and testing phases ; (b) predicted data agree quite well with from 06.30 am till 18.40 p.m

5. Conclusion

This study has attempted to develop a model that can be used to predict hourly total and solar radiation on the horizontal surface using the artificial neural networks method. Three statistical criteria were adopted: absolute error, r-squared and correlation of determination. The proposed artificial neural networks model can be predicted solar radiation with 7 variables. It observed that temperature (23.74 %), time (19.66 %), wind chill (24.14 %) and pressure (23.95 %) effect dominantly on radiation of solar. Solar radiation is increased with increase of temperature and wind chill, whereas solar radiation reduce when increase of humidity. Coefficients of determination (R^2) were found to be 0.9794 and 0.9892 for the solar radiation during training and testing phases, respectively. This study confirms the ability of the ANN to predict solar radiation values precisely. The results indicate that the ANN model seems promising for evaluating the solar resource potential at the places where there are no monitoring stations in Pekan.

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