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Research Article

GLOBAL SOLAR RADIATION FORECASTING BASED ON METEOROLOGICAL DATA USING ARTIFICIAL NEURAL NETWORK

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ABSTRACT

The main objective of this work is to predict average daily global solar radiation (GSR) without any measuring instruments , in future time domain for Madurai city, located in Tamilnadu (India) by using Standard multilayered feed-forward, back-propagation neural network with Levenberg-Marquardt (LM) training algorithm and Gradient descent back propagation (GD) algorithm. In order to train and test the neural network, three different artificial neural network models are developed, based on daily average meteorological data like maximum ambient air temperature, minimum ambient air temperature and minimum relative humidity values for predicting global solar radiation. The measured data were randomly selected for training, validation and testing the neural network. The results from the three artificial neural network models shows that using the minimum air temperature and day of the year outperforms the other cases with absolute mean percentage error of 5.36% and mean square error of 0.006 when training was done by using LM back propagation learning algorithm. From the results it is very clear that neural network is well capable of estimating GSR from simple and available meteorological data. It is expected that the models developed for daily global solar radiation will be useful to the designers of energy-related systems as well as to those who need to estimate the daily variation of global solar radiation for the specific location in Tamilnadu (India).

INTRODUCTION

Solar energy is the most ancient source, and it is the root material for almost all fossil and renewable types. Solar energy is freely available and could be easily harnessed to reduce our reliance on hydrocarbon-based energy by both, passive and active designs. Precise solar-radiation estimation tools are vital in the design of solar systems.

Solar resources are known to exhibit a high variation in space and time due to the influence of other climatic factors. For efficient conversion and utilization of the solar resource, the solar engineer designing solar energy systems requires an accurate and detailed short-term and long-term knowledge of the solar radiation characteristics of the location in various forms such models or maps for proper sizing of the solar energy systems (Shafiqur Rehman *et al*, 2008; Ozan Senkal *et al*, 2009; Fadare, 2009; Krishnaiah *et al*, 2007). Solar radiation models or maps are therefore essential design-input parameters in the assessment of solar energy systems.

Artificial neural network as an estimation tool has proved its efficiency in predicting different parameters via other parameters though their relationship is not specified. Climatological and meteorological parameters are important parameters in indicating the amount of solar radiation in a selected region. So applying artificial neural networks can be valuable in determining the effects of meteorological parameters and finally prediction of solar radiation.

There are several articles that have used artificial neural networks, for predicting solar radiation. Rehman *et al* (2009) applied ANN model for forecasting diffuse solar radiation in Saudi Arabia by using four combinations of data sets. Ghanbarzadeh *et al* (2009) predicted daily global solar radiation based on measured air temperature, relative humidity and sunshine hours values between 2002 and 2006 for Dezful city in Iran using artificial neural network (ANN) models. Özgür Solmaz *et al* (2010) predicted hourly solar radiation by using Standard back propagation and back propagation with momentum neural network.

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Mohamed Benghanem *et al* (2010) investigated Radial Basis Function (RBF) which is used for modelling and predicting the daily global solar radiation at Al-Madinah (Saudi Arabia) using other meteorological data such as air temperature, sunshine duration, and relative humidity . In recent years, ANN models were used by many researchers to estimate global solar radiation (Sozen and Arcaklioglu, 2005; Sozen *et al*, 2005).

Related works

Adnan Sozen *et al* (2004) estimated the solar-energy potential in Turkey using artificial neural-network (ANN). Scaled conjugate gradient (SCG), Pola-Ribiere conjugate gradient (PRCG), and Levenberg-Marquardt (LM) learning algorithms and a logistic sigmoid transfer function were used in the network. In order to train the neural network, meteorological data's was taken from eleven stations spread over Turkey and six stations data are used for testing. Meteorological and geographical data like latitude, longitude, altitude, month, mean sunshine duration, and mean temperature are used as inputs to the network. Solar radiation is the output layer. The trained and tested ANN models show greater accuracies for evaluating solar resource possibilities in regions where a network of monitoring stations has not been established in Turkey. The predicted solar-potential values from the ANN were given in the form of monthly maps. These maps are of prime importance for different working disciplines, like those of scientists, architects, meteorologists, and solar engineers in Turkey.

Shah Alam *et al* (2009) developed artificial neural network (ANN) models for estimating monthly mean hourly and daily diffuse solar radiation. Solar radiation data from 10 Indian stations, having different climatic conditions, all over India have been used for training and testing the ANN model. The feed forward back-propagation algorithm is used in this analysis. Results of ANN models have been compared with the measured data on the basis of percentage root-mean-square error (RMSE) and mean bias error (MBE). It is found that maximum value of RMSE in ANN model is 8.8%. This shows that ANN model is more accurate and versatile as compared to other models to predict hourly and daily diffuse solar radiation.

Ali A. Sabziparvar *et al* (2007) developed new method for the estimation of global solar radiation in the arid and semi-arid regions in Iran. Most of the models used so far, have provided solar estimation for a few specific locations based on the short-term solar observations. Using different radiation models, (e.g. Sabbagh, Paltridge-Proctor, Daneshyar) and various input parameters (e.g. cloud cover, sunshine duration, relative humidity, temperature, and altitude) we developed a general height-depended formula for the prediction of the direct and diffuse monthly average daily solar radiation for 64 mountainous arid and semi-arid locations in West and East Iran. The models mentioned are modified and new coefficients are defined for the diffuse component based on the long-term observed diffuse data. Model results are validated against up to 13-year daily solar observations at 10 solar radiation sites. In comparison with the previous studies, the newly developed method performs more accurate estimation in the arid and semi-arid regions.

Tymvios *et al* (2005) investigated comparative development of a variety of models for the estimation of solar radiation on a horizontal surface. By using two different methodologies, models of various complexities have been developed and tested. The first methodology refers to the traditional and long-utilized angstrom linear approach which is based on measurements of sunshine duration. The second methodology refers to the relatively new approach based on artificial neural networks (ANN) and it is not only based on sunshine duration measurements but also on other Climatological parameters. The above comparison of results render the ANN methodology as a promising alternative to the traditional approach for estimating global solar radiation, especially in cases where radiation measurements are not readily available.

Abdul Azeez *et al* (2011) used three meteorological parameters namely sunshine duration, maximum ambient temperature and relative humidity used for the analysis of solar irradiation in Gusau, Zamfara State of Nigeria. Artificial Neural Network was employed to obtain the predicted values of the average monthly solar radiation. The result shows an excellent agreement between measured and predicted values with coefficient of determination of 0.9996, maximum percentage error of 0.8512 and root-mean-square error of 0.0028. The comparison between the ANN model and some existing empirical models has shown the superiority of the ANN model.

Tamer Khatib *et al* (2012) presented a global solar energy estimation method using artificial neural networks (ANNs). This prediction was based on collected data from 28 sites in Malaysia. The clearness index is used to calculate global solar irradiations. The ANN model is based on the feed forward multilayer perception model with four inputs and one output. The inputs are latitude, longitude, day number and sunshine ratio; the output is the clearness index. Five main sites in Malaysia have been used to test the proposed approach. Based on the results, the average MAPE, mean bias error and root mean square error for the predicted global solar irradiation are 5.92%, 1.46% and 7.96% respectively.

In this paper, estimation of global solar radiation was done by using the following meteorological data like maximum ambient temperature, minimum ambient temperature, minimum relative humidity and day of the year as input to the network, which was measured at Madurai city located in Tamilnadu state of India. Levenberg-Marquardt (LM) training algorithm and Gradient descent back propagation (GD) algorithm was used in the present network.

Artificial Neural Network (ANN)

In general, ANN is simply mathematical techniques designed to accomplish a variety of tasks. The use of the ANN for modeling and prediction purposes has increasingly become popular in the last decades. ANN are composed of attributes that lead to perfect solutions in applications where we need to learn a linear or nonlinear mapping. Some of these attributes are: learning ability, generalization, parallel processing and error endurance. These attributes would cause the ANN to solve complex problems precisely and flexibly.

An Artificial Neural Network (ANN) is inspired from biological nervous systems. To train and test a neural network, input data and corresponding output values are necessary .An artificial neuron consists of five elements namely inputs, weights, summing function, activation function and outputs. An artificial neuron is shown in Figure 1.

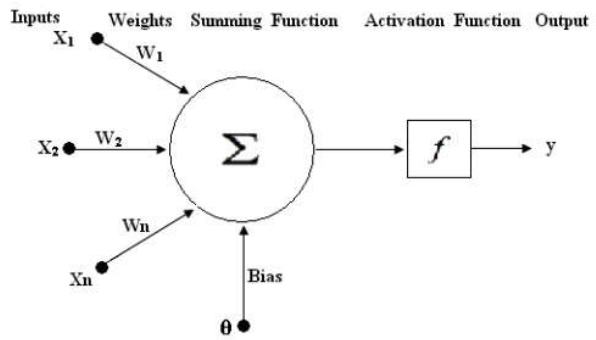

Figure 1 An artificial neuron

The values of x_1, x_2, x_n are inputs and w_1, w_2, w_n are weights. Each input is multiplied by the relevant weight. Obtaining products and bias are summarized. By applying activation function to the result of summary, the output of neuron is obtained.

There are three steps in solving an ANN problem which are 1) training 2) generalization and 3) learning. Training is a process that network learns to recognize present pattern from input data set together with the desired pattern of activities for the output units. Generalization or testing evaluates network ability in order to extract a feasible solution when the inputs are unknown to network and are not trained to network. We determine how closely the actual output of the network matches the desired output in new situations. In the learning process the values of interconnection weights are adjusted so that the network produces a better approximation of the desired output. The disadvantage is that its operation can be unpredictable, because the network finds out by itself how to solve the problem.

In the present study, feed-forward, back-propagation, multilayer perceptron artificial neural network models are developed and trained separately by using Levenberg-Marquardt (LM) training algorithm and Gradient descent back propagation (GD) algorithm on 'Neural Network Toolbox' in MATLAB version 2012 , to predict the average global solar radiation using the data of Madurai city taken from March 2010 to December 2010 was randomly selected for training and testing the data.

For model 1, day of the year and daily average maximum ambient temperature was used as inputs and GSR as output. In model 2, day of the year and daily average minimum value of ambient temperature were used as inputs and GSR as output. In model 3, daily average minimum ambient temperature and minimum relative humidity, along with day of the year, were used as inputs to the ANN model and GSR as output.

The aim of this study is to investigate the feasibility of using ANN to model the non-linear relationship between solar radiation and other easily measurable important meteorological parameters. Hence, the model can be used to predict the average global solar radiation potential for specific locations in Tamilnadu of India where there are no records of solar radiation with meteorological ground stations. The predicted solar radiation values from the model can be used easily for design and assessment of renewable energy application systems.

Design of the Artificial Neural Network Model

Multi-layer feed-forward back-propagation network with different architecture were designed using the 'Neural Network Toolbox version 2012 in MATLAB. The network consist of three layers: input layer, hidden layer and output layer. There are two input parameters for the models 1 and 2 and three input parameters for the model 3 and one output parameter average global solar radiation for all the three models. Two different algorithms (LM and GD method) with single and double hidden layer topologies were used and the number of neurons was also varied to enhance the generalization capability of the network. No transfer function was used for input layer, hyperbolic tangent sigmoid transfer function for hidden layer and linear transfer function (purelin) for output layer.

Selecting the number of neurons for the hidden layer is a complicated problem. So far, no mathematically justifiable method is available for determining the hidden elements. Too many network nodes will increase the training time of the network and weaken the generalization and forecasting ability of the network. The number of the hidden elements is obtained by trial and error. Training is started with a minimum number of elements, the number of these elements is constantly increased and re-training of the ANN is continued until satisfactory training is achieved. The number of the hidden elements used for satisfactory training is considered as the optimal number.

Training and testing of the model

Prior to the training process, both input and target data sets were normalized to range between -1 and +1. Levenberg-Marquardt (LM) and Gradient descent back propagation (GD) algorithm were used for the training and testing of networks. The input and target datasets were divided randomly into three subsets: training, validation and testing datasets. The following table 1 shows the minimum and maximum values of the variables used in the normalization.

Table 1 Maximum and Minimum values of variables for normalization

Si.No	Name of the variable	Minimum value	Maximum value
1	Maximum Ambient Temperature	22.76	33.57
2	Minimum Ambient Temperature	22.12	32.54
3	Minimum Relative Humidity	49.91	79.77
4	Average Global Solar Radiation	63.71	199.83

Data Description

In the present study, Levenberg-Marquardt (LM) training algorithm and Gradient descent back propagation (GD) algorithm are used for the estimation of average global solar radiation for Madurai, a city in the south region of the Tamilnadu state of India and daily maximum or minimum ambient air temperatures and/or minimum relative humidity as input to the ANN model. The data for 250 days during March 2010 and December 2010 were randomly selected for training and testing the data.

A one hour average data for ambient air temperature, relative humidity, global solar radiation at Madurai city is collected for 250 days during March 2010 and December 2010 from a weather monitoring station. Table 2 shows that the name of the various parameters used to develop the models 1, 2 & 3

respectively. Two different algorithms such as LM and GD methods are used for training the parameters as mentioned below by using various numbers of neurons.

Table 2 Developed models using different sets of input parameters and activation functions

Model	Input parameters	Output parameters	Activation Function	
			Hidden Layer	Output Layer
1	Day of the year & Maximum air temperature	GSR	Hyperbolic tangent sigmoid	Pure linear
2	Day of the year & Minimum air temperature	GSR	Hyperbolic tangent sigmoid	Pure linear
3	Day of the year , Minimum air temperature & Minimum relative humidity	GSR	Hyperbolic tangent sigmoid	Pure linear

RESULTS AND DISCUSSION

In this study, maximum ambient air temperature, minimum ambient air temperature, minimum relative humidity and average global solar radiation values were collected from Madurai station for 250 days during March 2010 and December 2010. The collected data's was used for training , validation and testing of the networks to predict the Global Solar Radiation (GSR) by using both Levenberg-Marquardt (LM) learning algorithm and Gradient descent back propagation (GD) algorithm.

First, a feed forward ANN was trained to estimate the global solar radiation based on the daily average maximum ambient air temperature and day of the year. Levenberg-Marquardt (LM) learning algorithm network with two inputs, 30 hidden neurons in one layer and one output unit was selected to find GSR. The root mean square error (RMSE) for these data was found to be 0.006, while the mean absolute error (MAE) was 5.533 %. Similarly the above mentioned data are trained by using Gradient descent back propagation (GD) algorithm with two inputs, 24 hidden neurons in one layer and one output. As a result, root mean square error (RMSE) for these data was found to be 0.014, while the mean absolute error (MAE) was 8.846 %.

To further explore the effect of daily minimum ambient air temperature on GSR, another feed forward ANN was trained to estimate GSR, based on the daily Minimum ambient air temperature and day of the year. A network of two inputs, 36 hidden neurons in one layer (For LM algorithm) and 32 hidden neurons in one layer (For GD algorithm) and one output of Average global solar radiation were found with the same data division as done in the previous case. The obtained root mean square error (RMSE) was 0.006 & 0.007 for the LM and GD algorithm respectively, while the mean absolute error (MAE) for above data's was 5.361% & 6.343% for the LM and GD algorithm respectively.

A neural network with three inputs, 36 hidden neurons in one layer (For LM algorithm) and two hidden layers with 36 hidden neurons in each layer (For GD algorithm) and one output unit was trained based on day of the year, daily minimum ambient air temperature and daily minimum relative humidity to predict the GSR. The same range of 250 days data's are used for training and testing. The root mean square error (RMSE) for this case based on LM and GD algorithm was 0.006 & 0.013 respectively, while the mean absolute error (MAE) based on LM and GD algorithm was 5.492% & 8.294% respectively.

Table 3 Comparison of root mean square error and mean absolute error for the developed ANN models

Name of the parameters	Model 1-Day & Max ambient air temp		Model 2-Day & Min ambient air temp		Model 3-Day , Min ambient air temp & Min RH	
Algorithm	LM	GD	LM	GD	LM	GD
Architecture	2-30-1	2-24-1	2-36-1	2-32-1	3-36-1	3-36-36-1
Neurons	30	24	36	32	36	36,36
Root Mean square error (RMSE)	0.006	0.014	0.006	0.007	0.006	0.013
Mean absolute error (MAE)	5.533	8.846	5.361	6.343	5.492	8.294

Table 3 shows the results of trained networks based on both Levenberg-Marquardt (LM) learning algorithm and Gradient descent back propagation (GD) algorithm. From this comparison it was clearly understood that, the network with the input parameters of day and minimum ambient air temperature by using Levenberg-Marquardt (LM) learning algorithm outperforms as compared to the other cases with root mean square error (RMSE) of 0.006 and mean absolute error (MAE) of 5.361%. Finally, for this case, when daily minimum ambient air temperature was used as input along with day of the year (LM-Model 2), shows the best performance, as compared to the other models.

The comparison between the predicted and the measured values of average global solar radiation of the neural network trained with the input parameters of day and minimum ambient air temperature (Model -2) by using Levenberg-Marquardt (LM) learning algorithm is shown in Fig.2. This shows that the ANN predicted global solar radiation values are very close to the measured values for all the datasets.

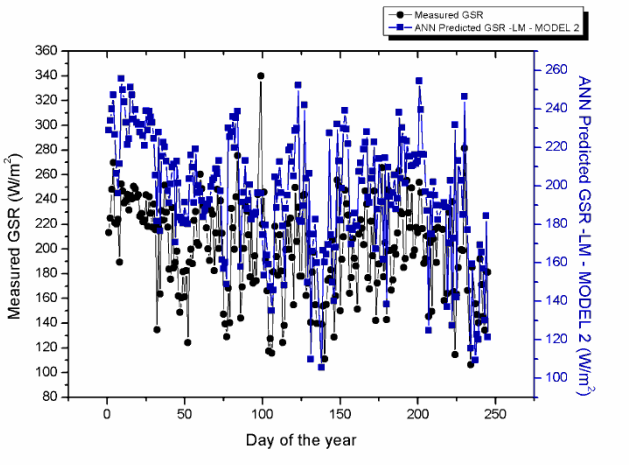

Figure 2 Comparison of measured GSR with ANN Predicted GSR

CONCLUSION

Construction of solar radiation database is very useful for solar energy, environmental, agricultural and other applications. Recently the use of artificial neural networks has developed widely as a prediction tool. Here global solar radiation (GSR)

values are predicted by using an ANN model, for the specific location Madurai , in Tamilnadu (India).

Two different algorithms such as Levenberg-Marquardt (LM) algorithm and Gradient descent back propagation (GD) algorithm are used for the training and testing of the networks. In this article, maximum ambient air temperature, minimum ambient air temperature, minimum relative humidity and average global solar radiation data are collected from Madurai station for 250 days during March 2010 and December 2010 was used for GSR prediction.

The above mentioned temperature and relative humidity parameters are commonly available in many places. Finally the results shows that , using the daily average minimum ambient air temperature along with day of the year trained by LM algorithm (LM- Model 2) outperforms the other cases with root mean square error (RMSE) of 0.006 and mean absolute error (MAE) of 5.361% .

This article presents the outcome of an attempt made to predict the average global solar radiation (GSR) based on measured values of temperature and relative humidity only. Global solar radiation (GSR) is costly to measure and requires continuous attention of skilled manpower while other parameters are commonly available parameters. The proposed model can be used for predicting daily global solar radiation accurately, which helps to design and development of renewable energy systems, for specific location Madurai, a city in the south region of the Tamilnadu (India), by using commonly available data of ambient air temperature.

References

Shafiqur Rehman and Mohamed Mohandes, (2008). Artificial neural network estimation of global solar radiation using air temperature and relative humidity. Energy Policy, 36, 571-576.

Ozan Senkal and Tuncay Kuleli, (2009). Estimation of solar radiation over Turkey using artificial neural network and satellite data. Applied Energy, 86, 1222-1228.

Fadare, D.A, (2009). Modelling of solar energy potential in Nigeria using an artificial neural network model. Applied Energy, 86, 1410-1422.

Krishnaiah, T., Srinivasa Rao, S., Madhumurthy, K., Reddy, K.S, (2007). Neural Network Approach for Modelling Global Solar Radiation. *Journal of Applied Sciences Research*, 3 (10), 1105-1111.

Rehman, S., and Mohandes, M, (2009). Estimation of Diffuse Fraction of Global Solar Radiation Using Artificial Neural Networks. Energy Sources, Part A, 31, 974 - 984.

Ghanbarzadeha, A., Noghrehabadia, A. R., Assareh, E., Behrang, M.A. (2009). Solar radiation forecasting based on meteorological data using artificial neural networks. 7th IEEE, International Conference on Industrial Informatics.

Özgür Solmaz., Humar Kahramanli., Ali Kahraman., Muammer Özgören, (2010). Prediction of daily solar radiation using ANNs For Selected Provinces In Turkey. International Scientific Conference, Gabrovo.

Mohamed Benghanem., and Adel Mellit, (2010) Radial Basis Function Network-based prediction of global solar radiation data: Application for sizing of a stand-alone photovoltaic system at Al-Madinah, Saudi Arabia. Energy, 35, 3751-3762.

Sozen, A., and Arcaklioglu, E, (2005). Effect of relative humidity on solar potential. Applied Energy, 82, 345-367.

Adnan Sozen., Erol Arcaklioglu., Mehmet Ozalpa, E., Galip Kanit, (2005). Solar-energy potential in Turkey. Applied Energy, 80, 367-381.

Adnan Sozen., Erol Arcaklioglu., Mehmet Ozalpa., Galip Kanit, E, (2004). Use of artificial neural networks for mapping of solar potential in Turkey. Applied Energy, 77, 273-286.

Shah Alam, Kaushik, S. C., Garg, S. N, (2009). Assessment of diffuse solar energy under general sky condition using artificial neural network. Applied Energy, 86, 554-564.

Ali A. Sabziparvar and Shetaee, H, (2007). Estimation of global solar radiation in arid and semi-arid climates of East and West Iran. Energy, 32, 649-655.

Tymvios, F.S., Jacovides, C.P., Michaelides, S.C., Scouteli, C, (2005). Comparative study of Angstrom's and artificial neural Networks methodologies in estimating global solar radiation. Solar Energy, 78, 752-762.

Abdul Azeez, M.A., (2011). Artificial Neural Network Estimation of Global Solar Radiation Using Meteorological Parameters in Gusau, Nigeria. Archives of Applied Science Research, 3(2), 586-595.

Tamer Khatib, Azah Mohamed, M., Mahmoud, Sopian, K., (2012). Estimating Global Solar Energy Using Multilayer Perception Artificial Neural Network. *International Journal of Energy*, 1(6), 25-33.

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