International Conference on Renewable Energies and Power Quality (ICREPQ'14)
Cordoba (Spain), 8th to 10th April, 2014
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, No.12, April 2014

Predicting global solar radiation for North Algeria

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Abstract. Having a complete and effective radiometric database is very crucial in the renewable energy field for the design of solar photovoltaic and thermal system. Despite the existence of the chain of radiometric measurement at the University of Blida, data acquisition of various components of radiation is still having problems, such as gaps in basic radiometric data due to heavy power-cuts especially in summers. Thus, a good design is only possible if the measurements are available continuously in space and time. Solar energy estimation procedures using artificial neural networks methods may overcome the issue. In this study, an artificial neural network (ANN) was used for the estimation of daily global solar radiation (DGSR) on horizontal surface using data measured from the meteorological station located inside the University. Six input parameters were used to train the network. These parameters were elevation, longitude, latitude, air temperature, relative humidity, and wind speed. The optimized network obtained with lowest error during the training was one with 6 neurons in the input layer; 6 neurons in the hidden which was obtained by trial and error, and one neuron in the output layer. The results show that the ANN can be accurately trained and that the chosen architecture can estimate the DGSR with acceptable accuracy: mean absolute error (MAE) less than 20% for both training and validation step.

Keywords

Artificial neural network; daily global solar radiation (DGSR); air temperature; wind speed; humidity

I. Introduction

Energy is necessary for the economic and social development and improved quality of life in Algeria and principally in Blida because it is an industrial city. It is located in the center of Algeria characterized by its very hot climate in summer and cold weather in winter. Therefore, the energy resources are of vital importance both economically and environmentally. Solar energy is being seriously considered for satisfying a significant part of energy demand in this region.

Artificial Neural networks (ANNs) are the nature-based computing techniques which have been applied widely in tasks such as prediction, optimization, etc. A three-layer feedforward artificial neural network can approximate any nonlinear continuous function to an arbitrary accuracy [1-2]. The use of ANNs to solve real problems always includes selecting the appropriate network models and network topology, as well as the efficient training algorithms [3, 4].

In this paper an ANN has been trained to predict the daily global solar radiation on horizontal surface at the University of Blida, which can help students to design solar prototypes.

II. Artificial neural network modelling

The methodology of modeling with ANN can be summarized in these steps:

1. Collecting database data from real meteorological station, scientific papers or analytic equations.
2. Pre-treatment and analysis of these data to delete the aberrant points.
3. Scaling the database data between [-1 and +1] in order to make learning process faster.
4. Dividing the database into three parts: training, test and validation to avoid the over training.
5. There is a combination of ANN parameters to be initialized randomly and to be selected after the learning process and having a desired error, such as:
   a. The performance of the best architecture can be measured statically, using the determination coefficient and different kind of errors like mean absolute error (MAE).
   b. Initialize randomly values of weights and biases to ensure a fast convergence, (we can make the networks life a lot easier by giving it data scaled in such a way that all the weights can remain in small, predictable ranges).

c. Initialize randomly the number of hidden layer and the number of neurons in each hidden layer.

d. Selecting the transfer function for the hidden and the output neurons (the same function for each layer).

e. The training algorithm for weights changing during a number of iterations.

6. Training, test and validation process using Levenberg-Marquardt back-propagation algorithm

7. Analysis and comparison of the ANN results with the experimental data.

III. Data set preparation

In this work, a data set of 14745 points of one year (2011) was used to develop the ANN model. All data base was taken from the meteorological station of Blida University recorded using Davis Vantage Pro2 Weather station. The meteorological data are: air temperature (TA (°C)), relative humidity RH (%), and wind speed Ws (ms^{-1}). Figure 1 shows the geographical location of the meteorological station.

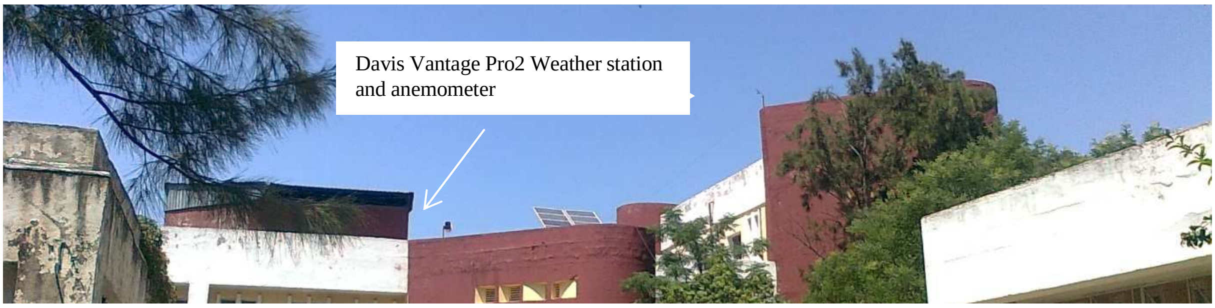

Fig. 1. Geographical location at the University of Blida of the meteorological station

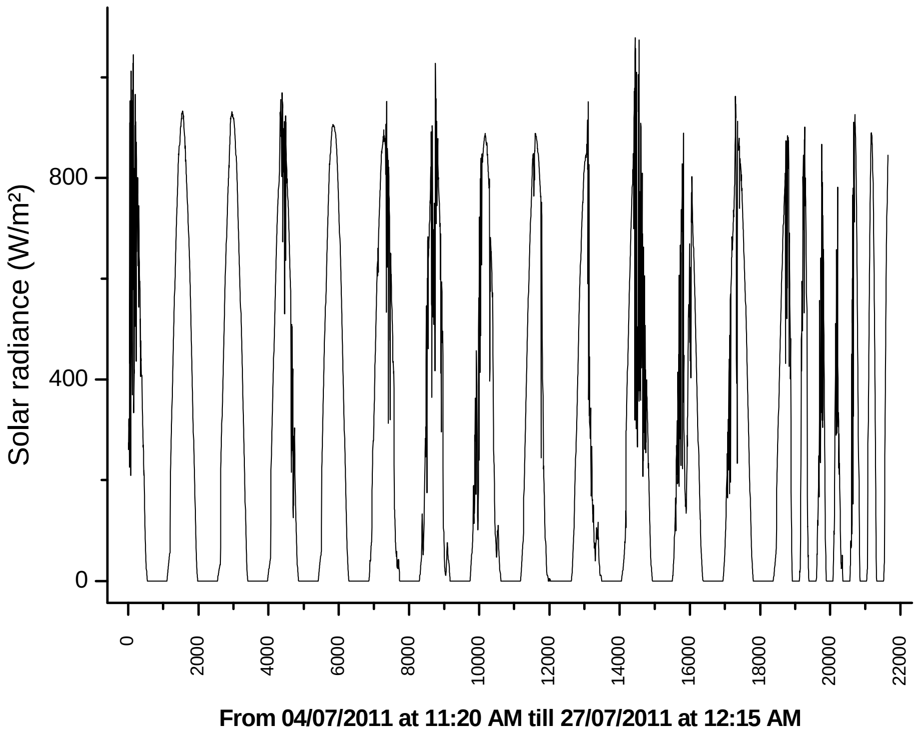

Fig. 2. Monthly distribution of solar radiation data

The monthly distribution of solar radiation data is presented in figure 2. Table 1 shows the basic information for weather station and the data ranges of the properties of interest. As seen in table 1, DGSR cover wide ranges going from 0 to 10.78 ($kWh.m^{-2}$), relative humidity from 17 to 92 (%), air temperature from 6.8 to 42.3 (°C) and wind speed from 0.4 to 2.2 ($m.s^{-1}$). As solar radiation changes with the geographical location, in this study we have used latitude, longitude and altitude as input parameters to make a difference. It means this model is valid under the region of test.

TABLE I. - Solar radiation database and basic information for weather station

Parameters	Value [min-max]
Altitude (m)	0120
Longitude	02.47E
Latitude (°N)	36.27
T_A (°C)	6.8 - 42.3
RH (%)	17 - 92
W_s (m/s)	0.4 - 2.2
DGSR (kWh/m²)	0 - 10.78
Period (yr)	2011
No. Data	14745

The weather station is successfully installed at Electronic Department (ED), Blida University. The main purpose of weather station installation is to improve the study in assessment of wind and solar energy especially for students to design and develop prototypes that work with renewable energy.

All these steps were written in MATLAB program searching for one best combinaison of ANN parametres. the supervised training was used in this study. Premnmx/postmnmx data scaling/descaling was done by coloumn using this function:

$$X^{scaling} = \frac{X_{old} - X_{\min}}{X_{\max} - X_{\min}}\left(Y_{\max} - Y_{\min}\right) + Y_{\min} \quad (1)$$

Here Y_{max} and Y_{min} are -1 and +1, respectively, x_{max} and x_{min} are the maximum and minimum values of individual input variable.

Table II. - Structure of the optimized artificial neural networks model.

Type of network	RNFF-BP (newff function of MatLab®)	
Layer	Nb. de neurones	Fonction d'activation
Input layer	06	---
Hidden layer	06	Tangent sigmoid (function Tansig of MatLab®)
Output layer	01	Linear (function Purelin of MatLab®)
Training Algorithm	Levenberg-Marquardt. (Trainlm of MatLab®).	

We used the back-propagation algorithm for training several multi-layer feed-forward neural networks to estimate the values of the daily global solar radiation. The best network consists of 6 inputs, 6 neurons in the hidden layer and one neuron in the output layer. The training process continues until the error function approaches a prespecified minimum value. After the training is completed, the developed model is used for testing, where 4915 is used. The found results indicate the viability of this method for the daily global solar radiation modeling. DGSR estimates from the ANN compared with the actual data using simple error analysis and linear analysis with the following parameters: coefficient of correlation (R) and mean absolute error (MAE). The correlation coefficient found is 0.81652.

IV. Conclusion

Daily global solar radiation (DGSR) data are desirable for many areas of research and applications in various engineering fields. However, DGSR is not as readily available as air temperature data. Various equations have been developed to compute the solar irradiation data measured on horizontal surface. These equations constitute the conventional approach. In this article, an alternative approach, generalized regression type of neural network, is used to predict the solar irradiation on horizontal surfaces, using the minimum number of variables involved in the physical process.

Artificial neural networks have been successfully used in recent years for optimization, prediction and modeling in energy systems as alternative to conventional modeling approaches.

Artificial neural networks (ANNs) are effective tools to model nonlinear systems and require fewer inputs. The objective of this study was to test an artificial neural network (ANN) for estimating the daily global solar radiation (DGSR) on horizontal surface as a function of air temperature, relative humidity and wind speed data in the north region of Algeria. The measured data of 2011 were used for training and testing the neural networks data. The testing data were not used in training the neural networks. Obtained results show that neural networks are well capable of estimating DGSR from temperature, relative humidity and wind speed. This can be used for estimating DGSR for locations where only temperature, humidity and wind speed data are available.

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