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The potential of different artificial neural network (ANN) techniques in daily global solar radiation modeling based on meteorological data

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Abstract

The main objective of present study is to predict daily global solar radiation (GSR) on a horizontal surface, based on meteorological variables, using different artificial neural network (ANN) techniques. Daily mean air temperature, relative humidity, sunshine hours, evaporation, and wind speed values between 2002 and 2006 for Dezful city in Iran (32°16′N, 48°25′E), are used in this study. In order to consider the effect of each meteorological variable on daily GSR prediction, six following combinations of input variables are considered:

(I) Day of the year, daily mean air temperature and relative humidity as inputs and daily GSR as output.
(II) Day of the year, daily mean air temperature and sunshine hours as inputs and daily GSR as output.
(III) Day of the year, daily mean air temperature, relative humidity and sunshine hours as inputs and daily GSR as output.
(IV) Day of the year, daily mean air temperature, relative humidity, sunshine hours and evaporation as inputs and daily GSR as output.
(V) Day of the year, daily mean air temperature, relative humidity, sunshine hours and wind speed as inputs and daily GSR as output.
(VI) Day of the year, daily mean air temperature, relative humidity, sunshine hours, evaporation and wind speed as inputs and daily GSR as output.

Multi-layer perceptron (MLP) and radial basis function (RBF) neural networks are applied for daily GSR modeling based on six proposed combinations.

The measured data between 2002 and 2005 are used to train the neural networks while the data for 214 days from 2006 are used as testing data.

The comparison of obtained results from ANNs and different conventional GSR prediction (CGSRP) models shows very good improvements (i.e. the predicted values of best ANN model (MLP-V) has a mean absolute percentage error (MAPE) about 5.21% versus 10.02% for best CGSRP model (CGSRP 5)).

Keywords: Multi-layer perceptron (MLP) neural networks; Radial basis function (RBF) neural networks; Global solar radiation (GSR); Meteorological parameters; Prediction

1. Introduction

The green sources of energy are solar, wind, biomass, hydro, tidal, wave, ocean, etc. Among these solar, wind and hydro are commonly used (Rehman and Mohandes, 2008). Solar energy has many different applications; analysis of the thermal load on buildings, solar energy collecting systems, atmospheric energy balance studies, etc. (Robaa, 2009). The values of the global solar radiation (GSR) are the most important parameter for the solar energy applications (Bakirci, 2009).

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Nomenclature

a, b, c, d	empirical coefficients of conventional models
H	daily global radiation (J/cm^2 day)
H_0	daily extra-terrestrial radiation (J/cm^2 day)
S	actual sunshine hour (h)
S_0	maximum possible sunshine duration (h)
I_{sc}	solar constant (= 1367 W m^{-2} = 11810.4 J cm^{-2} day^{-1})
E_0	eccentricity correction factor
δ	solar declination (deg)
ϕ	latitude of site (deg)
ω_s	sunrise hour angle (deg)
m	the number of the day of the year, starting from first January
RH	mean daily relative humidity (%)
T	mean daily air temperature (°C)
MAPE	mean absolute percentage error
R^2	absolute fraction of variance
MSE	mean square error
SSE	sum of square error
X_N	normalized value
X_R	the value to be normalized
$X_{\min}$	the minimum value in all the values for related variable
$X_{\max}$	the maximum value in all the values for related variable
$\mathrm{GSR}_{\mathrm{predicted}}$	predicted GSR
$\mathrm{GSR}_{\mathrm{actual}}$	actual GSR

For low-priced and effective development and utilization of solar energy, a complete knowledge about the accessibility and variability of solar radiation intensity in time and special domain is of great importance (Rehman and Mohandes, 2008). In developing countries, there are few solar observation sites, so the global solar radiation (GSR) measurements are usually made at few sites that may not be similar to the actual site of solar energy development and utilization. Studying the behavior of solar radiation at the intended site requires long-term data in a nearby location along with empirical, semi-empirical, physical, neural networks, wavelets, fractals, etc. techniques (Rehman and Mohandes, 2008). Extensive works have been done on Angstrom type of empirical models to estimate GSR on horizontal surface, and in these studies the measured sunshine duration values have been used (see Bakirci, 2009; Angstrom, 1924; Bahlel et al., 1987; Almorox and Hontoria, 1967; Akinoglu and Ecevit, 1990; Rehman, 1998; Aguiar and Collares-Pereira, 1992). Several conventional models have been presented by researchers to predict global solar radiation (GSR) using different meteorological variables (see Rehman and Mohandes, 2008; Robaa, 2009; lewis, 1983; Swartman and Ogunlade, 1967; Abdallah, 1994; Prieto et al., 2009). Using ANN has proved its efficiency as a prediction tool to predict factors through other input variables which have no any specified relationship. Meteorological and climatological variables are most comprehensive and important factors for indicating the amount of solar radiation in a selected reign (Azadeh et al., xxxx). Several studies have been presented to predict solar radiation using ANN (see Azadeh et al., xxxx; Elizondo et al., 1996; Al-Alawi and Al-Hinai, 1998; Togrul and Onat, 1999; Sozen et al., 2004, 2005; Yang and Koike, 2002; Mohandes et al., 1998, 2000; Hontoria et al., 2001, 2002; Tasadduq et al., 2002; Tymvios et al., 2005; Bosch et al., 2008; Mubiru and Banda, 2008).

Rehman and Mohandes, used air temperature, number of day and relative humidity as inputs to neural networks in order to estimate daily GSR for Abha city in Saudi Arabia. Results showed a mean absolute percentage error (MAPE) of 4.49% (Rehman and Mohandes, 2008).

Azadeh et al. used a multi-layer perceptron (MLP) neural network to predict monthly GSR by climatological and meteorological variables such as monthly mean maximum temperature, minimum temperature, relative humidity, vapor pressure, wind speed, duration of sunshine and total precipitation for six cities in Iran. The results showed an average MAPE and absolute fraction of variance (R^2) of 6.70% and 94%, respectively (Azadeh et al., xxxx).

Al-Alawi and Al-Hinai used location parameters, month, averages of pressure, temperature, vapor pressure, relative humidity, wind speed and sunshine duration as inputs into artificial neural network (ANN) models to predict GSR and achieved an accuracy about 7.3% as MAPE (Al-Alawi and Al-Hinai, 1998).

To predict the solar energy potential for 17 cities in Turkey, Sozen et al. used different meteorological and geographical factors (latitude, longitude, altitude, month, averages of sunshine duration, and mean temperature) as inputs of the neural networks. The data for 11 stations were used to train the neural networks and data from the other six stations were used for testing. The results showed a maximum mean absolute percentage error (MAPE) and absolute fraction of variance (R^2) of 6.7% and 99.89%, respectively (Sozen et al., 2004). In a different study which was done by Sozen et al., the solar potential for 12 cities spread over Turkey, was predicted using neural networks based on same meteorological and geographical factors. The data for nine stations were used in training the neural networks and data from the other three stations were used for testing. The obtained results showed a maximum mean absolute percentage error (MAPE) and absolute fraction of variance (R^2) of 6.78% and 99.78%, respectively (Sozen et al., 2005).

In two different works, Mohandes et al. used latitude, longitude, altitude and sunshine duration as inputs of