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Prediction of daily diffuse solar radiation using artificial neural networks

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ABSTRACT

This study presents two optimization techniques, genetic algorithm (GA) and particle swarm optimization (PSO), to improve the efficiency and generalization ability of back propagation neural network (BPNN) model for predicting daily diffuse solar radiation. Seven parameters including month of the year, sunshine duration, mean temperature, rainfall, wind speed, relative humidity, and daily global solar radiation are selected as the evaluating indices. The predictions from the BPNN optimized by PSO model were compared with those from two models: BPNN and BPNN optimized by GA. The results show that the proposed BPNN optimized by PSO model has potential in accurately predicting the daily diffuse solar radiation.

Introduction

Due to the rapid growth of the global energy demands, renewable energy sources are gaining more attention from researchers, governments and industries in recent years. Solar energy plays a vital role in providing a sustainable energy in the future. Solar energy is the portion of the sun's energy available at the earth's surface for useful applications, including raising the temperature of water or exciting electrons in a photovoltaic cell, supplying energy to natural processes [1]. Among them, generating hydrogen through solar energy via photovoltaic systems by electrolyzing water without emission of carbon dioxide or other hazardous gases from combustion of fossil fuels is considered to be an appealing target, especially in the locations with difficult accessibility to the electricity. For solar-hydrogen energy based system, one of the primary requirements is to gather and process precise solar radiation data. However, due to expensive cost and technology requirement, the devices for the measurements of solar radiation are not always available in many regions. Therefore, predicting the amount of solar radiation using mathematical models, especially daily diffuse solar radiation, is very important for designing and developing the solar-hydrogen energy based systems.

Many efforts have been made to estimate daily diffuse solar radiation recently. For example, Torres et al. [2] presented a comparison among seventeen different proposals for estimating the hourly diffuse fraction of irradiance. They concluded that the Boland–Ridley–Lauret (BRL) model is more easily applied than the Dirint model. Li et al. [3,4] proposed two models for estimating the diffuse solar radiation based on multiple predictors including the clearness index, relative sunshine duration, ambient temperature and relative humidity. They concluded that the two models can estimate the monthly average daily diffuse solar radiation with good accuracy.

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Karakoti et al. [5] developed seven generalized empirical models for estimating the diffuse solar radiation. They concluded that the seven suggested correlations are generalized equations for India and are able to estimate the monthly average daily diffuse irradiance on a horizontal surface for any of the Indian site. Bortolini et al. [6] presented a multi-location model to estimate the expected profiles of the horizontal daily diffuse component of solar radiation. They concluded that the proposed approach outperforms other models proposed by the literature, with reference to the geographical area of applicability. Sigal et al. [7] analyzed the potential for hydrogen production from three major renewable resources (wind energy, solar energy and biomass) in Argentina and created a new geographic information system (GIS) of renewable hydrogen. Their results envisage an optimal scenario for a future hydrogen economy in Argentina. Magarreiro et al. [8] reviewed solar radiation models for predicting hourly diffuse fraction from global radiation. They concluded that the re-calibration of the Boland–Ridley–Lauret (BRL) model and the exploitation of new predictors should be exploited in future work in order to enhance the robustness of a new model more suitable for the studied region. Tapakis et al. [9] compared empirical analytical correlations for the computation of the hourly diffuse fraction based on data obtained from the actinometric meteorological station in Athalassa, Cyprus, for the period 2001–2013. They concluded that the introduction of additional parameters such as the influence of time and seasons may improve the accuracy of the models and should be further investigated, using non-parametric analysis such as artificial neural networks. Bakirci [10] established some new empirical models for predicting the monthly mean diffuse solar radiation on a horizontal surface for typical cities in Turkey. It was concluded that the best performance can be achieved for the third-order polynomial model based on sunshine duration and clearness index. Yaniktepe and Genc [11] established a new third order polynomial model for predicting the global solar radiation on horizontal surface. They concluded that the proposed model is highly acceptable for predicting the solar radiation to produce electricity for hydrogen production. Despotovic et al. [12] assessed and compared different diffuse solar models using ten statistical quantitative indicators. Their results are visually presented by means of Taylor diagrams, which give a clear picture of how close a particular model is to measured data and how it is relatively compared to other models. Khorasanizadeh et al. [13] predicted the horizontal diffuse solar radiation using clearness index based empirical models. They concluded that the employment of these only clearness index based models for any solar system application, in particular solar hydrogen production, is convenient; given that the knowledge of clearness index only requires the global solar radiation data. Mohamed et al. [14] discussed the possibility of generating solar hydrogen in the Sahara region. They concluded that the highest ratio of hydrogen production at different locations varies according to solar radiation.

Artificial neural networks (ANNs) are flexible modeling tools with capabilities of learning the mathematical mapping between input and output variables of nonlinear systems [15]. In recent year, ANNs have been successfully applied in estimating global solar radiation. For example, Alam et al. [16] developed an ANN model to estimate monthly mean hourly and daily diffuse solar radiation. They concluded that ANN model is more accurate and versatile as compared to other models. Rizwan et al. [17] adopted a fuzzy logic based model to estimate the global solar energy. They concluded that the performance of the suggested model is satisfactory. Shamshirband et al. [18] proposed a kernel extreme learning machine (KELM) to predict daily global solar radiation from air temperature. They concluded that KELM offers favorable predictions and outperforms the support vector regression (SVR) model. Piri et al. [19] estimated the solar radiation using support vector regression (SVR) model. They concluded that SVR techniques outperform the sunshine duration-based empirical models. Mohammadi et al. [20] adopted the support vector regression (SVR) model to estimate the horizontal global solar radiation. They investigated the capability of two SVRs of radial basis function (rbf) and polynomial basis function (poly), and concluded that the SVR-rbf is highly qualified for horizontal global solar radiation estimation. Mohammadi et al. [21] proposed a new hybrid approach by combing the support vector machine (SVM) with wavelet transform (WT) algorithm to predict horizontal global solar radiation. They concluded that the proposed SVM-WT model shows higher performance than other well-known techniques such as artificial neural network (ANN), genetic programming (GP), and autoregressive and moving average (ARMA) model. Mohammadi et al. [22] adopted an adaptive neuro-fuzzy inference system (ANFIS) model to estimate the daily horizontal global solar radiation. They concluded that the proposed ANFIS model can be utilized to estimate the horizontal global solar radiation with favorable level of reliability and precision. Olatomiwa et al. [23] investigated the potential of support vector regression (SVR) for solar radiation prediction in Nigeria. They concluded that SVR with polynomial basis outperforms SVR with radial basis function and other methodologies in solar radiation estimation of the studied site. Olatomiwa et al. [24] proposed a hybrid machine learning approach by combining support vector machine (SVM) with firefly algorithm (FFA) to predict the monthly mean horizontal global solar radiation. They concluded that the developed SVM-FFA model can be adjudged as an efficient machine learning technique for accurate prediction of horizontal global solar radiation. Shamshirband et al. [25] adopted the extreme learning machine (ELM) to predict horizontal global solar radiation. They concluded that the ELM technique can provide reliable predictions with further precision compared to the existing techniques, such as SVM, GP and ANN. Olatomiwa et al. [26] investigated the accuracy of ANFIS for predicting solar radiation based on a series of measured meteorological data. They concluded that the proposed ANFIS model can be deemed as an efficient technique to predict global solar radiation for practical purposes. Shamshirband et al. [27] developed a coupled model for estimating daily horizontal diffuse solar radiation by integrating the support vector machine (SVM) with wavelet transform (WT) algorithm. They concluded that the proposed SVM-WT is an efficient method which enjoys much higher precision than other models, especially the 3rd degree empirical model. Shamshirband et al. [28] adopted a neural network auto-regressive model with exogenous inputs (NN-ARX) to predict daily horizontal global solar radiation. They concluded that the NN-ARX would be an efficient alternative approach to predict daily horizontal global solar radiation.

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