Available online at www.sciencedirect.com
SCIENCE DIRECT
Renewable Energy 30 (2005) 1075–1090
RENEWABLE ENERGY
www.elsevier.com/locate/renene

Forecasting based on neural network approach of solar potential in Turkey

Adnan Sözen[a,*], Erol Arcaklıoğlu[b], Mehmet Özalp[a], Naci Çağlar[c]

[a]*Mechanical Education Department, Technical Education Faculty, Gazi University, Teknikokullar, 06503 Ankara, Turkey*
[b]*Mechanical Engineering Department, Engineering Faculty, Kırıkkale University, Kırıkkale 71450, Turkey*
[c]*Engineering Faculty, Sakarya University, Sakarya, Turkey*

Received 21 February 2004; accepted 13 September 2004
Available online 16 December 2004

Abstract

As Turkey lies near the sunny belt between 36 and 42°N latitudes, most of the locations in Turkey receive abundant solar energy. Average annual temperature is 18–20 °C on the south coast, falls down to 14–16 °C on the west coast, and fluctuates 4–18 °C in the central parts. The yearly average solar radiation is 3.6 kW h/m^2 day, and the total yearly radiation period is ~2610 h. The main focus of this study is put forward to solar energy potential in Turkey using artificial neural networks (ANNs). Scaled conjugate gradient (SCG), Pola-Ribiere conjugate gradient (CGP), and Levenberg–Marquardt (LM) learning algorithms and logistic sigmoid transfer function were used in the network. In order to train the neural network, meteorological data for last 4 years (2000–2003) from 12 cities (Çanakkale, Kars, Hakkari, Sakarya, Erzurum, Zonguldak, Balıkesir, Artvin, Çorum, Konya, Siirt, Tekirdağ) spread over Turkey were used as training (nine stations) and testing (three stations) data. Meteorological and geographical data (latitude, longitude, altitude, month, mean sunshine duration, and mean temperature) is used as input to the network. Solar radiation is the output. The maximum mean absolute percentage error was found to be less than 6.78% and R^2 values to be about 99.7768% for the testing stations. These values were found to be 5.283 and 99.897% for the training stations. The trained and tested ANN models show greater accuracy for evaluating solar resource posibilities in regions where a network of monitoring stations have not been established in

* Corresponding author. Tel.: +90 312 212 6820/1873; fax: +90 312 212 0059.
E-mail address: asozen@gazi.edu.tr (A. Sözen).
URL: http://w3.gazi.edu.tr/~asozen

doi:10.1016/j.renene.2004.09.020

Turkey. The predictions from ANN models could enable scientists to locate and design solar energy systems in Turkey and determine the best solar technology.

Keywords: Solar energy potential; City; Turkey; Artifıcial neural network

1. Introduction

Turkey is located at the Mediterranean at 36 and 42°N latitudes and has a typical Mediterranean climate. Solar energy potential is very high in Turkey. The yearly average solar radiation is 3.6 kW h/m^2 day, and the total yearly radiation period is ~2610 h. Solar radiation incident on a horizontal surface and sunshine duration are measured by all recording stations in Turkey [1]. Several studies have individually been presented [2–6] for the prediction of solar radiation in various cities in Turkey. Our few studies have been presented for prediction of solar resource in several cities in Turkey using artificial neural network (ANN) [7–8]. In this study, the cities used in training and testing are different based on meteorological and geographical properties than Refs. [7–8]. Also, this study proves that ANN can be used prediction of solar resource in Turkey.

For efficient conversion and utilization of the solar energy, engineers designing solar energy systems require an accurate detailed long-term knowledge of available global solar radiation data in various forms, depending on the related application. This study shows general perspective of solar resource in Turkey. Twelve stations (namely cities: Çanakkale, Kars, Hakkari, Sakarya, Erzurum, Zonguldak, Balıkesir, Artvin, Çorum, Konya, Siirt, Tekirdağ) are selected in different regions of Turkey in which the radiation data and sunshine duration information are being collected since 2000. The cities selected can give a general idea about solar resource of Turkey. In this study, estimation of solar potential in Turkey based on meteorological and geographical data was performed using artificial neural networks (ANNs). Scaled conjugate gradient (SCG), Pola-Ribiere conjugate gradient (CGP), and Levenberg–Marquardt (LM) learning algorithms and logistic sigmoid transfer function were used in the network. Meteorological and geographical data (latitude, longitude, altitude, month, mean sunshine duration, and mean temperature) is used as input to the network. Solar radiation is the output. A reasonably accurate knowledge of the solar resource availability at any place is required by solar engineers, architects and meteorologists in many application areas of solar energy.

2. Artificial neural networks

Artificial neural networks (ANNs) have been widely used for many areas, such as control, data compression, forecasting, optimization, pattern recognition, classification, speech, vision, etc. The use of the ANNs for modelling and prediction purposes is increasingly becoming popular in the last decades [9–21]. ANNs have been trained to overcome the limitations of the conventional approaches to solve complex problems. ANNs can be trained to solve problems that are difficult to model analytically.