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Solar energy potentials in Iran: A review

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ABSTRACT

In the present study, feasibility of using solar energy in different regions of Iran is investigated. For this purpose, maximum, minimum, and average values of annual horizontal radiation were calculated for sixty-three stations. Then, monthly and annual clearness indices and the annual average horizontal radiation map and GIS maps of horizontal radiation (GHR) were prepared for each month of the year. The results show that central and southern regions in Iran, except the coastal areas in the south, receive higher quantities of horizontal radiation. Among these regions, Southern Khorasan and Khuzestan provinces receive significant amounts of solar radiation such that the use of solar systems in these regions will be more economical. Delgan, Mahshahr, Shushtar, Abadeh, and Fadashk stations recorded an annual average horizontal radiation of above 500 W/m^2, which shows their potential for photovoltaic applications. These regions may be recommended for further study.

Contents

1. Introduction

Energy is known as the driving engine for economic development the world over. Global energy resources can be classified into the three main groups of fossil energies (oil, gas, coal, etc.), nuclear energy, and renewable energies (wind, solar, geothermal, hydropower, biomass, hydrogen, ocean, etc.). Industrial development and higher living standards have led to an increasing demand for energy, especially in the form of electrical energy. The global energy consumption is estimated to rise in 2035 to around 32.922 TW (about twice as much as its consumption in 2008) [1].

Given the limited sources of fossil fuels and nuclear energy and their rather rapid depletion, their replacement with new sources seems to be inevitable. Besides, fossil fuels are dangerously associated with carbon dioxide emissions that get trapped in the lower layers of the atmosphere and lead to extreme climate changes, floods, torrential rains, and droughts in many parts of the world [2].

Renewable energies eliminate the problems associated with fossil and nuclear energies such as pollution and environmental damages. Moreover, these resources are inexhaustible. Thus, they seem to be suitable alternatives to both fossil fuels and nuclear energy. Only of a recent origin, the technology to exploit these resources is nowadays growing rapidly. Sustainable development goals of the millennia in the energy sector and the need for enhanced energy security through recourse to different energy

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resources are included among the main factors that have attracted immediate attention on a global scale to the development and advancement of renewable energies [3]. A dramatic increase is being currently witnessed in activities and investments by both public and private sectors in the research, development, and supply of new technologies in the field. It is as a result of such activities that the unit cost of power generation from renewable resources has remarkably decreased, making these resources more competitive than ever compared to conventional power generation systems.

Solar energy is a renewable energy which has attracted special attention in many countries. If only 0.1% of the solar energy incident on the earth can be converted to electrical energy at an efficiency rate of 10%, 3000 GW of power will be generated, which is by four times more than the energy consumed annually on a global scale [4]. In addition to the advantages of renewable energies mentioned above, the use of solar energy is additionally associated with greater benefits as follows:

1. Reclamation of degraded lands;
2. Reduced reliance on national power grid network;
3. Improved water quality across the nation; and
4. Acceleration in electrification of rural areas [5].

Iran is located in the Middle East and holds large reserves of oil and gas (9% of the global oil reserves and more than 15% of the global gas reserves) [6]. However, the domestic use of fossil fuels has increased dramatically due to its population explosion, industrial development, and higher living standards, a situation that may lead in the near future to its drastically reduced oil exports. Based on statistical report releases, Iran is among the top 20 countries in terms of greenhouse gas production. In 2008, the rate of carbon dioxide emission (in kilograms) to Gross Domestic Production (in US$) was 3.15, whereas the global average was 0.73. This is one major reason for turning to new sources of energy [7]. Although the use of renewable energies in Iran dates back to a decade ago, its full development and use are still in their embryonic stages [8].

Located between 25° and 40° north latitude, Iran is in a favorable position with respect to the potential amount of solar energy received. Solar radiation in Iran is estimated at about 1800 to 2200 kW h/m^2 per year, which is higher than the global average. An annual average of more than 280 sunny days is reportedly recorded over more than 90% of Iran's territorial land, which yields a highly significant potential source of energy. Thus, it is essential to estimate the exact amounts of radiation in different parts of Iran for designing optimum solar facilities.

The amount of radiation incidence on a point of Earth's surface depends on several factors, namely altitude, latitude, fraction of sunshine hours, relative humidity, precipitation, and air temperature. Several models have been developed to estimate the total amount of solar radiation on horizontal surfaces using various climatic parameters such as sunshine hours, cloudiness, relative humidity, minimum and maximum temperatures, wind speed, and so forth [9–11].

Wu et al. [12] used the Nanchang weather station (China) data from 1994 to 2005 to predict the daily total radiation by sunshine hours, ambient temperature, total precipitation, and dew point. Sen [13] proposed a nonlinear model to estimate the total solar radiation using the sunshine hours data available. Recently, Bulut and Buyukalaca [14] proposed a simple model to estimate the monthly average of daily total radiation on horizontal surfaces. The model is based on a sinusoidal function which only depends on a single parameter called 'the number of the year's day'. The model was able to estimate the monthly average values of daily total radiation in 68 provinces in Turkey with high accuracy. Paltridge and Proctor [15] used latitude and cloudiness to estimate direct and diffuse radiation. Fadare [16] used geographical and meteorological data from 195 cities in Nigeria over a ten-year period (1983 to 1993) to predict the solar potential energy using neural networks. In another study, Bakirci [17] investigated radiation estimating models associated with sunshine hours. Gastli and Charabi [18] predicted the solar energy potential for power generation in Oman using GIS maps. In their study, they first reviewed the methods developed for creating solar radiation maps using GIS tools and then developed Oman's solar radiation GIS maps for the months of January and July. They also used a number of methods to calculate the annual electrical energy generation potential. The results showed that the country had the potential to use solar energy all year long. Kelley et al. [19] investigated the feasibility of using solar energy for water transport. They proposed a method for calculating the feasibility of water transport by photovoltaic power systems based on the regional climate.

Investigating 16 different radiation models, Rehman [20] used altitude, latitude, and absorption coefficient to calculate the daily radiation in 41 cities in Saudi Arabia and compared the results. In another study, Al-Ayed et al. [21] proposed some empirical correlations and used one-year data (1986) to calculate the daily total, diffuse, and direct radiation quantities on horizontal surfaces in Riyadh. Several correlations among solar parameters have also been proposed by Benghanem and Joraid [22] to estimate the monthly average values of total and diffuse radiations in Medina. Sorapipatana [23] evaluated the potential for using solar energy in Thailand, using a satellite technique. The results showed that the average solar radiation largely depends on geographic features rather than on seasonal changes.

A number of studies have been conducted in Iran to estimate solar radiation. Using the model proposed by Paltridge and Proctor and one year data, Daneshyar [24] proposed a modified model for solar radiation in Tehran. Jafarpur and Yaghoubi [25] estimated monthly and annual radiation quantities in Shiraz. In another work, Samimi [26] proposed an altitude-dependent model using Meinel and Meinel model [27]. He used Sun–Earth correction, cloudiness coefficient, sunshine hours, and altitude to predict daily radiation in different parts of Iran. Following Samimi's work, Yaghubi and Sabzevari [28] used sunshine hours to calculate clearness index for Shiraz. In another study, Sabziparvar [29] selected the best model for Iran's coastal cities, using six solar radiation estimation models and compared the results with measured data. Sabziparvar and Shetaee [10] investigated six common models for estimating radiation in Iran's eastern and western arid and semiarid areas, and eventually proposed a new model for these areas. Their results showed that models based on cloudiness are capable of yielding more accurate estimations of radiation in Iran.

In the present study, the feasibility of exploiting solar energy in different parts of Iran is investigated. For this purpose and as the first step, average, maximum, and minimum values of solar radiation on a horizontal surface are calculated at different stations. Then, the monthly and average clearness indices are determined using the radiation data obtained from these stations and the average monthly summation of sunshine hours is calculated. Finally, GIS maps of average monthly and annual radiation are developed.

2. Iran

Iran (also known as Persia) is a vast country located in southwest Asia. Covering an area of 1648,195 km^2, it is the 18th