Renewable Energy 35 (2010) 515–519

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Measurement of solar-energy (direct beam radiation) in Abu Dhabi, UAE

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ARTICLE INFO

Article history:
Received 11 June 2009
Accepted 23 July 2009
Available online 18 August 2009

Keywords:
Clearness index
Direct beam radiation
Pyroheliometer
Meteorological information
Solar energy

ABSTRACT

This paper presents actual measurements of direct solar radiation in Abu Dhabi (24.43°N, 54.45°E) with the existing meteorological conditions encountered during the measurement throughout the year. High resolution, real-time solar radiation and other meteorological data were collected and processed. Daily and monthly statistics of direct solar radiation were calculated from the one-minute average recorded by a Middleton Solar DN5-E Pyroheliometer. The highest daily and monthly mean solar radiation values were recorded as 730 and 493.5 W/m^2, respectively. The highest one-minute average daily solar radiation was recorded as 937 W/m^2. In addition to direct beam radiation, the daily average clearness indexes, surface temperature variations, wind speeds and relative humidity variations are discussed. When possible, direct beam radiation and some meteorological data are compared with corresponding data of the 22-year average of NASA's surface meteorology and solar-energy model. The measured data (direct beam radiation and meteorological) are in close agreement with the NASA SSE model with some discrepancy.

1. Introduction

Continual depletion of conventional energy sources (fossil fuels), coupled with increases in industrial emissions of CO_2 to the atmosphere and their consequent impact on climate, has motivated the search for renewable energy sources to satisfy the human needs. Renewable energy sources, such as solar and wind energy, are being considered for future energy source because, they are abundant, clean, cost-free. In order to harvest these energy sources, procuring data on their availability in specific localities is an essential task. Knowledge of solar radiation data at a given location, the focus of this study, is important for the design and development of solar energy-based projects. In particular, the direct beam radiation data for any location are extremely important when concentrating solar collectors which are used in solar thermal power plant and concentrated photovoltaic systems. This information is also necessary for the early design stages of a project such as, the cost analysis, and performance simulations of the system. In particular, the clearness index of the area, in addition to other meteorological information such as humidity, wind speed and surface temperature for a specific period, is very important for assessing the feasibility of a solar- driven project.

The region of the Earth between latitudes of 40°N and 40°S is generally referred to as the "solar belt", where an abundant supply of solar radiation falls. Studies have shown that daylight at 25°N exists about 4449 h/year and that 70% of this is sunshine [1]. Due to its geographical position in the solar belt, the UAE is blessed with an abundance of solar energy in addition to fossil fuel. The UAE therefore has the opportunity to utilize this bounty of natural energy effectively, promoting a clean environment, and developing renewable energy technologies in the region.

The United Arab Emirates experienced a rapid increase in the electricity consumption between 1980 and 2000; this consumption continues today. Electricity consumption increased from 5.5 billion kWh in 1980 to about 36 billion kWh in 2000 with an annual growth rate of 10% compared to a world average of 3% [2]. Solar energy can help meet the region's electricity demand. For example, the use of photovoltaic devices, on the one hand, is suitable for rural electrification, pumping water from wells, cathodic protection for pipelines, telecommunications, and building facades. Solar thermal devices, on the other hand, can be used for sea-water desalination, crop drying, and water heating. Given these many possible uses of solar energy, it is important to know the global and direct beam radiation distribution throughout the year for the region.

Though global solar radiation has been measured at the various parts in the Persian Gulf region [3–10], direct beam radiation data is still incomplete. Many models have been developed, and many studies based on these models have been performed to estimate

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doi:10.1016/j.renene.2009.07.019

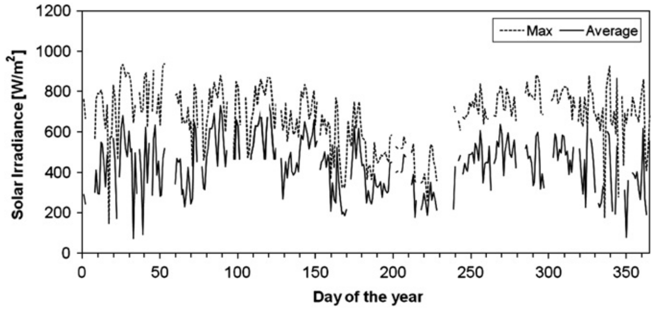

Fig. 1. Daily averages and daily peaks of direct beam solar radiation throughout the year.

Table 1
Monthly mean daily values of direct beam solar radiation for Abu Dhabi.

Months	Direct radiation, H(KWh/m^2/day)	
	Present measurement	NASA SSE model [19] (22-year average)
Jan	5.16	5.89
Feb	4.95	6.06
Mar	5.56	5.43
Apr	5.89	6.44
May	5.92	7.54
Jun	4.77	7.47
Jul	4.25	6.06
Aug	3.63	6.23
Sep	5.74	6.68
Oct	5.69	6.90
Nov	5.31	6.63
Dec	4.07	5.57

solar energy. Monthly average solar radiation on the sloped surface in Dhahran was studied by Al-Sulaiman and Ismail [11], who used the Isotropic sky model. A statistical assessment of the accuracy of 12 solar radiation models for five meteorological stations in the Gulf Arabian states was performed by Al Mahdi et al. [12]. Global and diffuse solar radiations in Doha were measured by Abdalla and Baghdady [13]. They examined some of the methods of predicting global solar radiation. The diffuse component of solar radiation was predicted by two methods, which showed almost similar results. These results were then compared with the measured values of diffuse solar radiation in Dhahran. Elhadidy et al. [14] measured ultraviolet solar radiation at Dhahran for one complete year. The solar-energy potential of north-east Saudi Arabia was investigated by Sahin et al. [15]. They measured the complete one-year data and discussed the clearness index. Solar radiation data for Amman was measured by Hamdan [16], who found that the annual average daily total solar radiation was 20.4 MJ/m^2, while diffuse radiation was 4.5 MJ/m^2. The monthly average daily global solar radiation for Oman was investigated by Al-Hinani and Al-Alawi [17]. They measured the daily data of global solar radiation at six stations over a period of six years and then estimated the clearness index for a typical day for each location. Khalil and Alnajjar [18] performed an experimental and theoretical investigation of only global and diffuse solar radiation in the UAE. As this study shows, global solar radiation data have been reported for many Gulf regions and most of these Gulf regions have high solar-energy potential. However, reliable and yearlong direct beam radiation data for Abu Dhabi is still lacking. Global solar radiation data except direct normal is not enough for the calculation of cooling and heating loads of the buildings, designing solar power plants, etc. The measurement of direct beam radiation is thus very important in the harsh environment like this region. For this study, we measured solar-energy radiation for one complete year. We then supported our measurements by comparing them with the 22-year average data from the NASA Surface Meteorology and Solar-Energy model [19]. Significant meteorological data were also measured for the specific period.

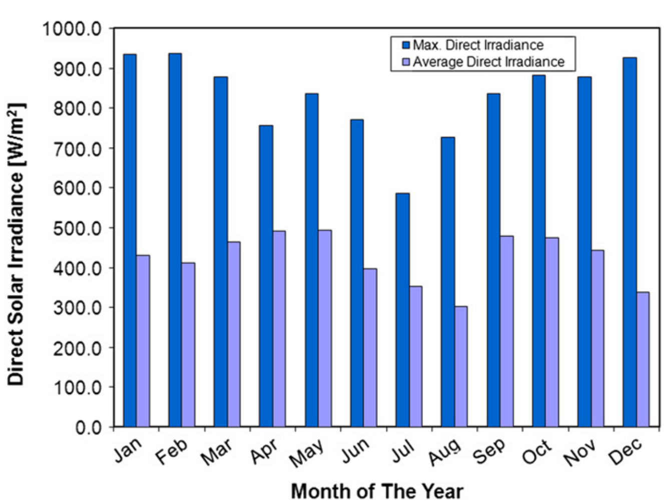

Fig. 2. Monthly averages and monthly peaks daily direct beam solar radiation.

2. Experimental setup and procedure

The measurement station was located at the Petroleum Institute of the capital city of the UAE, Abu Dhabi (24.43°N, 54.45°E). This study was carried out in 2007 for a complete year. The meteorological data and the direct beam radiation measurement instruments were set 15 m from the ground level. A Middleton Solar DN5-E Pyroheliometer was used to measure the direct beam radiation. Its calibration accuracy is ±2%, its sensitivity is 1.00 mV/Wm^{-2} with the range of irradiance 0–4000 Wm^{-2}; its operating temperature and humidity are −40 to + 60 °C and 0–100% RH, respectively; its spectral range is 200–5000 nm while the temperature output sensor is a YSl 44031 thermistor (10 KΩ @25 °C). A Virtual Weather Hawk weather station was placed at the same level to collect meteorological data. The Weather Hawk measures surface air temperature, relative humidity, and wind speed. To measure the air temperature, the Weather Hawk has a thermistor sensor of accuracy ±0.9 °F (±°C); a range of: −40° to + 120 °F (−40° to + 50 °C) and 0–100% RH, and temperature interchangeability of ±0.9 °F (±0.2 °C). To measure relative humidity the Weather Hawk

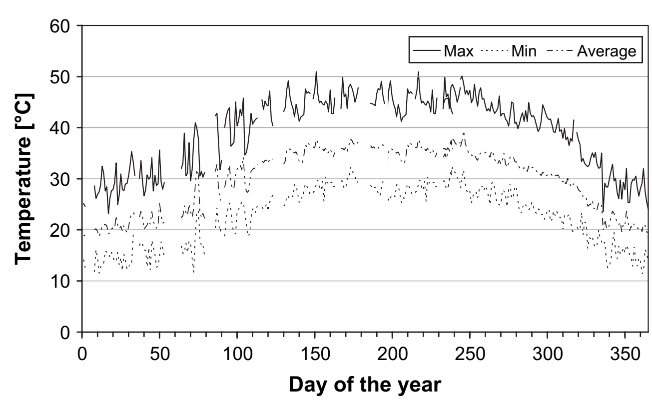

Fig. 3. Daily averages, minimum and maximum temperatures throughout the year (adopted from Islam et al. [20]).