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Measurement of solar energy radiation in Abu Dhabi, UAE

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ABSTRACT

This paper presents data on measurement of actual solar radiation in Abu Dhabi (24.43°N, 54.45°E). Global solar radiation and surface temperatures were measured and analyzed for one complete year. High resolution, real-time solar radiation and other meteorological data were collected and processed. Daily and monthly average solar radiation values were calculated from the one-minute average recorded values. The highest daily and monthly mean solar radiation values were 369 and 290 W/m^2, respectively. The highest one-minute average daily solar radiation was 1041 W/m^2. Yearly average daily energy input was 18.48 MJ/m^2/day. Besides the global solar radiation, the daily and monthly average clearness indexes along with temperature variations are discussed. When possible, global solar energy radiation and some meteorological data are compared with corresponding data in other Arab state capitals. The data collected indicate that Abu Dhabi has a strong potential for solar energy capture.

1. Introduction

Accurate information on the intensity of solar radiation at a given location is of essential to the development of solar energy-based projects. This information is used in the design of a project, in cost analysis, and in calculations on the efficiency of a project. In particular, the clearness index of the area, in addition to other meteorological information such as humidity and, temperature for a specific period, is extremely important to assess 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 has the opportunity to utilize this bounty of natural energy effectively, promoting a clean environment, and developing renewable energy technologies in the region. 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 solar radiation distribution throughout the year for the region.

Global solar radiation has been measured at the various parts in the Persian Gulf region [2–9]. Many models have been developed, and many studies based on these models have been performed to estimate solar energy. Monthly average solar radiation on the sloped surface in Dhahran was studied by Al-Sulaiman and Ismail [10], 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 done by Al Mahdi et al. [11]. Global and diffuse solar radiations in Doha were measured by Abdalla and Baghdady [12]. 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. Ultraviolet solar radiation was measured at Dhahran for a one complete year by Elhadidy et al. [13]. The solar energy potential of north-east Saudi Arabia was investigated by Sahin et al. [14]. They measured the complete one-year data and discussed the clearness index. Solar radiation data for Amman was measured by Hamdan [15], who found that the annual average daily total solar radiation was 20.4 MJ/m^2, while that 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 [16]. 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. Most parts of these gulf regions have high solar energy potential. As this literature review shows, although solar radiation data have been reported for many Gulf regions, reliable and yearlong global radiation data is still needed for Abu Dhabi. This study therefore addresses this need. For this study, we measured solar energy radiation for a one complete year. We then supported our measurements by comparing them with the 22-year average

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data from the NASA surface meteorology and solar energy model [17]. Finally, we compared our global solar radiation measurements with that of other Arab state capitals [18] to show the solar energy potential of Abu Dhabi region. Significant meteorological data were also measured for the specific period.

2. Experimental setup and procedure

The site of the measurement station was located at the Petroleum Institute of the capital city, Abu Dhabi (24.43°N, 54.45°E) of the UAE. This study was carried out in 2007 for a complete year. The surface air temperature and the global solar radiation measurement instruments were set 15 m from the ground level. A Middleton Solar EQ08-E First Class pyranometer was used to measure the global solar radiation. Its calibration accuracy is ±3%, its shortwave sensitivity is 1.00 mV/Wm^{-2}, and its response time (95%) is 11.7 s. A Virtual Weather Hawk weather station was placed at the same level to collect meteorological data. The Weather Hawk station had a silicon pyranometer of accuracy ±2%, a range of: 0–2000 W/m^2, temperature sensor accuracy of ±0.5 °C, and temp sensor of 10 k thermistor. A Weather Hawk data logger and a solar energy radiation data acquisition system were installed in the solar energy laboratory of the Petroleum Institute. The meteorological data were collected every minute using two similar computers. Both the pyranometer and the meteorological sensors were cleaned for one week to check the difference between the two readings of the different pyranometers. After one week, the Model Middleton Solar EQ08-E First Class pyranometer was cleaned every day, while the meteorological sensor was cleaned periodically. Meteorological sensors were checked, and quality control was implemented to ensure the quality of the collected data. Global solar radiation data from the two pyranometers were checked for comparisons, but there were no significant differences. As the Middleton Solar EQ08-E First Class pyranometer is highly sensitive, we used the data from this pyranometer. From the raw data stored for every minute, the mean, maximum and minimum hourly values were calculated. From the hourly data set, daily and monthly statistics were made for the solar radiation and temperature data.

3. Results and discussions

From the data it is clear that the daily average and maximum global radiation as well as temperatures are higher in summer time and lower in the winter. Fig. 1 describes the daily average and daily maximum global solar radiation for the whole year of 2007. The graphs show that the daily maximum global radiation of 1041 W/m^2 was recorded on February 8, while the highest daily average solar radiation of 369 W/m^2 was recorded on May 3. Daily mean solar radiation values were high during the period of 3 May–24 August. Average daily energy input for the whole year was 18.48 MJ/m^2/day, which agrees with the global solar map [19]. Fig. 1 also shows downward excursions in winter, especially in January and December. These excursions might be due to sandstorms, rain events and higher air mass in winter. The higher air mass in winter somewhat reduces the clear sky data by the absorption along the longer path length.

Daily averages for each month and peak daily global solar radiations for the complete year, including the error bars, are shown in Fig. 2. The month of May had the highest monthly average daily radiation of 290 W/m^2, but the month of February shows the highest daily peak in solar radiation of 1041 W/m^2. December had the lowest monthly average daily solar radiation of 131 W/m^2. The error bars in the monthly average mean values of global solar radiation are less than 5%, which indicates that the seasonal variation of the mean values is significant. Next we compared our measurements of the monthly mean daily values of global solar radiation for Abu Dhabi (MJ/m^2/day) with the larger time-series data of the NASA SSE model [17] and Abdalla et al. [2], as shown in Table 1. Our measurements agreed with the 22-year average global solar radiation data of the NASA SSE model. Our measurements were also comparable to the 10-year average data of Abdalla et al. Thus, our measurements for the year 2007 can be considered representative. We also compared the monthly mean daily values of global solar radiation of Abu Dhabi with some other Arab state capitals reported by Al Naser et al. [18], as shown in Table 2. In Table 2, it is clear that the monthly average global radiation over the course of the year is comparatively higher for Abu Dhabi, though in summer months a few Arab state capitals have higher values. The an-

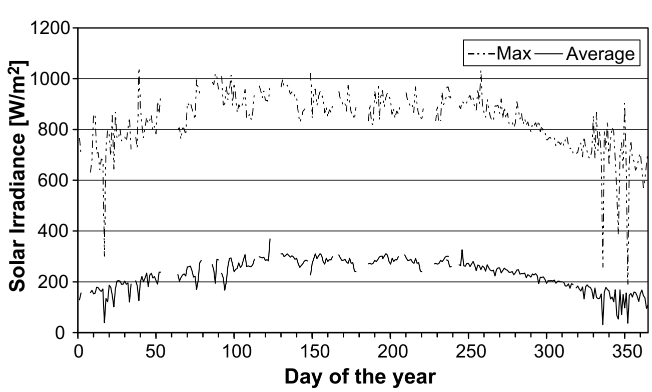

Fig. 1. Daily averages and daily peaks of global solar radiations throughout the year.

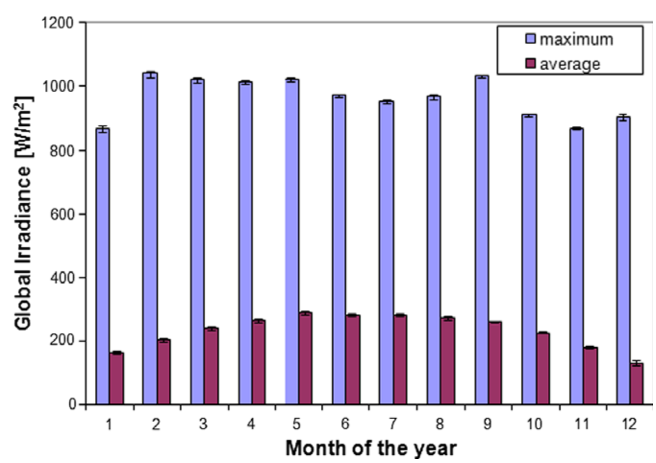

Fig. 2. Monthly averages and monthly peaks daily total solar radiation.

Table 1
Monthly mean daily values of global solar radiation for Abu Dhabi

Months	Global radiation, H (MJ/m^2/day)		
	Present measurement	NASA SSE model [17] (22-year average)	Abdalla et al. [2] (Average 1971–1980)
January	14.08	14.72	12.17
February	17.42	17.28	15.52
March	20.63	18.83	17.78
April	22.79	22.75	21.46
May	25.06	25.85	23.58
June	24.62	26.03	22.97
July	24.52	23.22	21.74
August	23.51	22.75	20.41
September	22.32	21.78	19.44
October	19.40	19.40	17.17
November	15.26	16.31	14.62
December	11.30	13.61	12.38