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The insolation on vertical surface having different directions in the Kingdom of Bahrain

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Abstract

The daily total global (H_T) and diffuse (H_{DIF}) solar radiation, measured at Bahrain International Airport, Kingdom of Bahrain, (latitude 26° 13″N and longitude 50° 39″E), had been recorded, analyzed, and studied. The mean hourly values of H_T and H_{DIF} on horizontal and vertical surfaces (facing North, South, East and West) have been averaged to daily and monthly radiation. The monthly average global solar radiation on a horizontal, vertical north, vertical east, vertical south and vertical west was 22.5, 4.0, 9.4, 11.9 and 11.3MJ/m^2, respectively. The monthly average of the diffuse (H_{DIF}) and direct (H_{DIR}) insolation was found 6.9 and 15.4MJ/m^2, respectively. The direct radiation represents, on average, 69.4% of the total insolation while the diffuse represents 30.6% of it. In comparing these values with previously measured total direct and diffuse in 1996 at the University of Bahrain, Isa Town campus, Kingdom of Bahrain (latitude 26° 20″N and longitude 50° 5″E), we found that the previous records give less percentage of H_{DIR}/H than the recent ones by 10.7%, while the opposite is true for H_{DIF}/H, as the recent is larger by 24.5%. This might be attributed either to the difference in the accuracy of the sensors or to the reduction in the atmospheric pollution, bearing in mind that the distance between the two places does not exceed 50 km. The total insolation incident on vertical west-facing surface was found to, on average, be larger than east facing by 20.2%, and as much as by 50.8% in January and larger by only 11.9% in July.

Keywords: Total and diffuse solar irradiation; Vertical surfaces; Insolation; Daylight; Sustainable buildings

1. Introduction

Bahrain is located at 26.24°N and 50.8°E. It is in the region of the earth between latitudes of 40°N and 40°S, that region is generally referred to the solar belt, where an abundant supply of solar irradiation falls, with the sunshine duration of about 4450 h, and 70% of this sunshine is a clear sky [1,2].

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Table 1
The results of calibration of the sensors

Line	Sensors	UK calib (mV/W/m^2)	UK calib (mV/W/m^2)	Bah calib (mV/W/m^2)	Drift (%)
Ch 09	G	4.72 e – 03	211.9	217.8	2.8
Ch 10	N	4.64 e – 03	215.5	221.0	2.5
Ch 11	E	4.62 e – 03	216.5	207.8	–4.0
Ch 12	S	4.65 e – 03	215.1	209.0	–2.8
Ch 13	W	4.66 e – 03	214.6	222.5	3.7
Ch 14	D	4.68 e – 03	213.7	219.1	2.5

Bahrain is located in the eastern side of Saudi Arabia, consisting of a semi-desert region—due to its extremely low precipitation rate (80 mm/yr), high temperature (up to 45°C). The region had occasional heavy sandstorms during summer and late springtime [3]. This makes the demand for electricity for air conditioning is extremely high. Recently, the demand reached 1500MW, which was in peak of summer (August). Seventy percent of this demand goes for air conditioning. The incorrect architectural design for buildings in this region augments the demand for electricity for cooling and ventilation. Furthermore, the lack of insolation data on vertical surfaces and the improper sizing of the passive insolation into buildings make situations even worse. In fact, within the Arab Gulf region, diffuse and global irradiations on a horizontal plane are currently recorded in a limited number of locations. However, nearly no single station exists to measure the total solar irradiation on vertical surfaces facing North, West, South and West.

The rising cost of electricity as well as the concern of the global environment change has provided the motive for making best use of daylight. Muneer [4] has shown that savings of 20–40% are attainable for office buildings, which utilize daylight effectively.

The electricity production in the Kingdom of Bahrain during 2000 was nearly 7 billion kWh and the consumption was nearly 6 billion kWh. The benefits associated with daylight design are several folds. Reduction of electrical lighting load due to the increased contribution of daylight will result in lower sensible heat gains. This has the knock-on effect of lowering the cooling requirements of a building's air conditioning. As cooling plants are high consumers of electricity, the costs associated with their operation can be as much as four times greater than those of heating. Also the overall efficiency of a cooling plant is only 5%, owing to the energy conversions associated with refrigeration and losses accumulating from electricity generation, transmission, and final consumption. Thus any reduction in electrical lighting load produces a much larger saving in primary energy consumption [4].

This study presents the measurements and analysis of one full year (2002) of the actual total solar irradiation on a horizontal and four vertical surfaces (North, West, South, and East), as well as the diffuse solar irradiation in the Kingdom of Bahrain.

2. Apparatus and data collection

A Solar Radiation Station (Commission Inter national de L'Eclairage-CIE) was installed on top of the administration building (4 m above ground) at the Directorate of Meteorology, Civil Aviation at Bahrain International Airport in Muharraq Island (latitude 26° 13′N and longitude 50° 39′E). The station consists of six pyranometers with a hemispherical field of view. They measure 5-min. average data on horizontal and vertical surfaces (North, East, South, and West).