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Original Article/Research

New model to estimate and evaluate the solar radiation

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Abstract

This research work proposed a new model used to predict the direct, diffuse and global solar flues for clear skies, by making the comparison between the numerical simulation of this model and the climatology measured data of Energetic Laboratory station the Faculty of science of Tetouan city (35.57361 latitude, −5.37528 longitude) in Northern Morocco.

The results indicate that the proposed model can be successfully used to estimate the solar radiation during all the seasons of year for studied position and for considered day, using as input the altitude (degrees), longitude (degrees) and latitude (m).

Keywords: Solar radiation; Solar irradiation; Meteorological parameters; Numerical simulation; Renewable energy

1. Introduction

The estimation of global solar radiation is essential for utilization the solar energy, design wherever appropriate observations missing (Iqbal, 1983). The values of solar radiation in clear skies are useful for determining the maximum performance heating and photovoltaic as well as for the design of air conditioning equipment in buildings or for the determination of thermal load their solar installations (Chiron de La Casinière, 2003).

Sizing and optimal management of energy systems can only be achieved by knowing the weather conditions that extensive studies are carried out in several parts of the world to assess and model the solar potential (Bekkouche, 2008).

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1.1. Measurements and used model

1.1.1. Instrument of measurements

The measurement of global and diffuse radiations at ground was performed by:

- a pyranometer (global solar radiation). This instrument measures the radiation incident on horizontal surface blackened from a solid angle of 2π steradians. The spectral range covers wavelengths from 0.3 to 3 μm. The received radiation is converted to heat by the blackened surface. The temperature difference between the surface and the body of the instrument is proportional to the irradiance of the global radiation; it is measured by a thermopile consisting of several thermocouples connected in series (La Météorologie, 2000).
- a similar pyranometer (diffuse solar radiation) having an added shades band obscure the direct radiation. Depending on circumstances, this screen maybe either a disk or a sphere (La Météorologie, 2000).

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Nomenclature

G_h	global flux received on a horizontal surface (W/m^2)	ψ	Azimuth of the sun (degrees)
I_h	direct flux received on a horizontal surface (W/m^2)	δ	solar declination (degrees)
D_h	diffuse flux received on a horizontal surface (W/m^2)	E_r	mean deference (dimensionless)
I_0	Solar constant (W/m^2)	ω	hour angle (degrees)
C_t	correction of the earth–sun distance	φ	latitude at local studied (degrees)
h	height of the sun (degrees)	λ	longitude at local studied (degrees)
T_{sv}	true solar time (hours)	z	altitude at local studied (m)
		τ_e	sunshine duration (hours)
		τ_j	duration day (hours)
		Γ	the turbidity factor (dimensionless)

1.1.2. Model of calculations

The Solar radiation who reaches the ground is formed by a direct radiation and a diffuse radiation which they are together form the global radiation (Bernard et al., 1980; Bertrand, 1980), we dedicate these respectful radiation respectively by the letters I (direct), D (diffuse) et G (global), all these are calculated with W m^{-2}.

1.1.2.1. Solar radiation on a horizontal surface full south.

1.1.2.1.1. Direct solar flux. It can be calculated by the formula:

$$I_h = I_0.C_t.\Gamma.\exp\left(-\frac{0.13}{\sin(h)}\right).\sin(h) \tag{1}$$

I_0 (W/m^2) is the solar constant, which is defined as the energy flux received by a unit area, in our case, the value that was selected 1367 W/m (Fekih and Saighi, 2010; Wong and Chow, 2001), Γ (dimensionless) is the turbidity atmospheric factor for clear skies (Capderou, 1987; Bouhadda et and Serrir, 2006), Can be calculated by the formula:

$$\Gamma = 0.796 - 0.01.\sin[0.986.(j+284)] \tag{2}$$

C_t (dimensionless) is the correction of the earth–sun distance can be calculated by the equation (Vienne; Ch, Perrin de Brichambrant et Ch, Vauge, 1982):

$$C_t = 1 + 0.034.\cos(j-2) \tag{3}$$

h (degrees) is the height of the sun, can be calculated by the following formula (Daniel and Gautret, 2008; Vienne; Hamdani, 2010):

$$h = \sin^{-1}(\sin(\varphi).\sin(\delta) + \cos(\varphi).\cos(\delta).\cos(\omega)) \tag{4}$$

δ (degrees) is the solar declination can be calculated by the approximate formula given by Cooper (1969) (Daniel and Gautret, 2008; Bird, 1984; La Gennusa and Rizzo, 2007):

$$\delta = 23.45.\sin(0.986.(j+284)) \tag{5}$$

where j is the day number of the year, ranging from 1 on 1 January to 365 on 31 December.

φ (degrees) is the latitude, in this case the Tetouan city in northern Morocco, is given in Table 1:

ω (degrees) is the hour angle of the sun, can be calculated by the following equation (Daniel and Gautret, 2008; Hamdani, 2010):

$$\omega = 15.(12 - T_{sv}) \tag{6}$$

T_{sv} (hours) is the true solar time of the study site, it is determined by the formula (Daniel et al., 2008; Nia et al., 2013):

$$T_{sv} = T_l - DT_l + (D_{hg} + E/60)/60 \tag{7}$$

- T_l: local time.
- DT_l: advance the local time through standard time.
- D_{hg}: the time difference (advance of 4 min per degree).
- E: equation of time, which is calculated by the equation (Raoui et al., 2011):

$$E = 450.8.\sin(2.\pi.j/365 - 0.026903) + 595.4.\sin(4.\pi.j/365 + 0.352835) \tag{8}$$

This formula gives time in seconds.

1.1.2.1.2. Diffuse solar flux. It can be calculated by the formula:

$$D_h = 120.\Gamma.\exp\left(-\frac{1}{(0.4511 + \sin(h))}\right) \tag{9}$$

1.1.2.1.3. Global solar flux. It is the sum of the direct and diffuse solar radiation (Yaïche and Bekkouche, 2008; Mesri-Merad et al., 2012):

$$G_h = I_h + D_h \tag{10}$$

Table 1
The geographical coordinates of the position study.

Position studied	Latitude	Longitude	Altitude
Tetouan City in northern Morocco	−5.37528	35.57361	1