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Calculation and Analysis of Total Quantity of Solar Radiation Incident on the Horizontal Surface of Babylon

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Conclusion

This study includes mathematical methods to calculate the total amount of solar radiation falling on the horizontal surface of the city of Hilla, for the unit of area, which can be applied on the ground in order to use photo voltage cells for the electrical energy needed to feed the required loads, weather data have been relied on temperature, relative humidity, dust and clouds for the period from 1/9/2012 to 05/01/2013 which taken from the Meteorological station of Education College for Pure Sciences - University of Babylon, as well as data from the Meteorological station of Sciences College - University of Babylon for the period from 1/5/2012 to 01/09/2012 located on longitude (44.401^o) and width (32.4^o), which have a direct impact on the angle of the fall of the solar radiation. The results showed that the amount of solar radiation calculated theoretically for the city of Hilla per m^2 was the reality within the range 0-945 W / m^2.

The study also proved that weathering has a direct impact on the amount of solar radiation measured through decreasing it by the processes of absorption and scattering depending on the diameter of particles, dust and water vapor (the amount of relative humidity) in the air and the type and thickness and height of the clouds.

Introduction

In a lot of applications for solar energy, such as electric power generation by solar cells, the calculation or estimation of the amount of solar energy falling on the Squared area on the surface of the earth is of paramount importance so it is natural to identify the factors influencing the amount of solar radiation and these factors are summarized as follows: (nature radiation, geographic location, components of the atmosphere, time, date and weather conditions).

That's where the earth receives daily 174 megawatts from the sun in the upper layers of the atmosphere, and when the sun's rays enter into the atmosphere 6% reflect, and absorbs 16%, noting that the weather natural conditions, (such as clouds, pollution) reduces the severity of radiation of the sun during their passage through the atmosphere by 20% due to reflection and 3% due to absorption.

These weather conditions do not reduce only the amount of energy reached to the Earth's surface, but also publishes nearly 20% of the sunlight coming and ran part of the nice, and after passing through the atmosphere, half of the sun almost become within the visible spectrum (ie up to 0.473 microns) The other half it is often within the infrared spectrum (a small part of the ultraviolet rays) and the following two figures illustrate the mechanisms of the spread of solar radiation in the air and a nice connecting solar radiation to the earth's surface, respectively. [1]

Theoretical calculations

The amount of solar radiation for a certain dotted connector is the final outcome of each angle of solar radiation (which determine UVR) and duration of sunshine [2] It is therefore clear that there are many mathematical relationships that are connected to describe the amount of solar radiation connecting to the earth's surface.

The relationship Ankström (Angistrom) of the most important relationships as the amount of solar radiation connecting to the surface of the earth, this relationship assumes a linear relationship between solar radiation and sunshine duration as follows [3].

$$\frac{Q}{Q_A} = a + b\frac{n}{N} \quad \text{......................} \ (1)$$

Where

Q - Hourly values of total solar radiation incident on a horizontal surface.

Q_A - Total radiation outside the atmosphere.

a, b-constants depend on location.

n-number of hours the brightness of the sun operation.

N-brightness hours theory.

The approximate values of the constants are given depending on the latitude given by:

$$a = 0.29 * \cos\theta$$
$$b = 0.25 \quad at \quad 60\ south < \theta < 60\ north$$

Where θ is Latitude.

As well as Q_A given by:

$$Q_A = \frac{s \cos z}{L^2} \quad \text{..................(2)}$$

Where

S-solar radiation constant which equal to 1367 W/m^2.

z - Angle of the solar dimension (ie Solar Azimuth Angle rely on Latitude)

L - The ratio between the real dimension of the sun at any moment and the rate of the earth from the sun (0.843) [4].

The position of the sun is given in terms of the azimuthal angle dimension (z) and described in Figure 1, which depend on the time (of the day) as well as longitude and latitude where the time in hours as described [3].

$$t = t_s + 0.17\sin\left(\frac{4\pi j - 80}{373}\right) - 0.129\sin\left(\frac{2\pi(j-1)}{355}\right) + \frac{12(s_m - l)}{\pi} \quad \text{.......(3)}$$

Where

t_s - The theoretical time or the daylight hours.

j - day of the year (1-365),

s_m - Longitude standard rad units which is equal to 45 * π/180,

For the purpose of description of the position of the sun we can define two quantities are (θ_s, φ_s) (zenith angle, azimuth angle) (horizontal dimension angle and azimuth head), respectively, of the 2 relationships[2]:

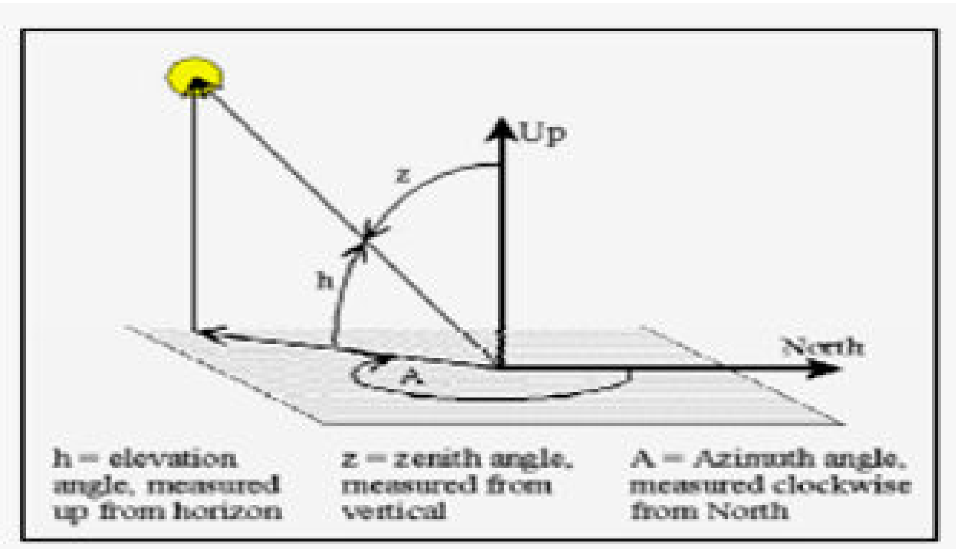
$$\theta_s = \frac{\pi}{2} - \sin^{-1}(\sin\alpha \sin\delta - \cos\alpha \cos\delta \cos\frac{\pi t}{12}) \quad \text{...............(4)}$$

$$\varphi_s = \tan^{-1}\left\{\frac{-\cos\delta \sin \pi t}{\cos\alpha \cos\delta - \sin\alpha \cos\frac{\pi t}{12}}\right\} \quad \text{.......................(5)}$$

Where α, δ solar declination of the sun and the time the sun angle, respectively.

t - the time of day (daylight hours).

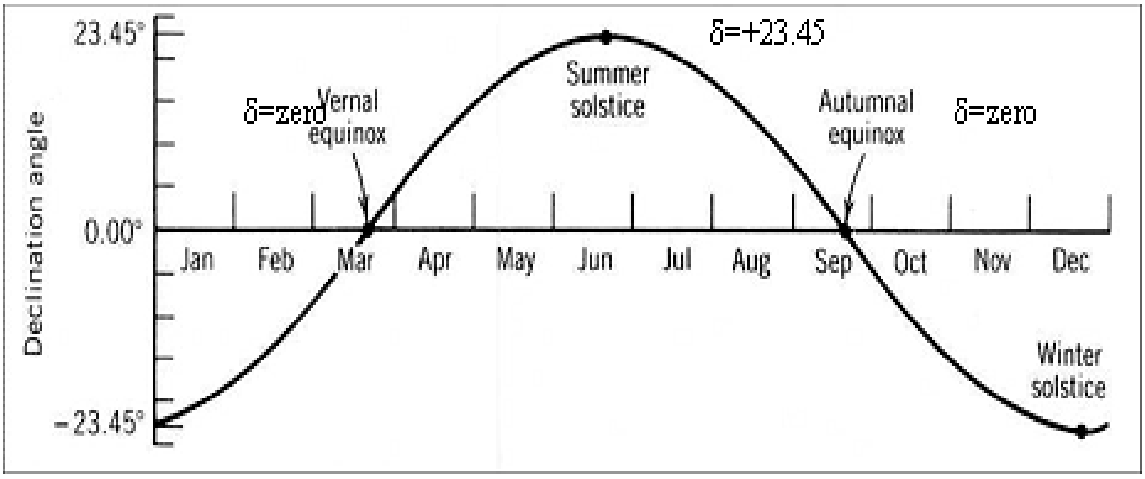
The following figure shows the position of the sun in terms of the azimuthal angle dimension(z). [4]



.[2] (Figure 1) the position of the sun in terms of azimuth of the sun. **(z)**

Elevation angle of the sun - representing the angular height measured from the horizon of the observer to the position of the sun in the sky [2].

Angle of the horizontal dimension of the sun - is the angle which are made by sunbeam hometown at the level of the horizon of the observer [2].
Azimuth head - is the angle between SMT and monitoring the position of the sun [2].
Hour angle of the sun - is the angular measurement of time equal to 15 degrees per hour[2].
Inclination angle of the sun - is the angle between the sun and the equator heavenly [2]. and Figure 2 shows the change of it as a function of the sequence of the day.



(Figure 2) change the angle of inclination of the sun as a function of the sequence of the day **[5]**

One of the natural phenomena facing the spread of electromagnetic waves through the atmosphere is the attenuation or extinction is known as a decrease happening in the energy of electromagnetic radiation through the transition for certain distance in the atmosphere, including attenuation both absorption and the solar rays scattering by particles that make up the atmosphere and the observed the differing density and particle radii from one area to another in the atmosphere and which know turbid air represents the bulk of the processes happening attenuation of the ray passing through [3].

The turbid air represents ratio between the optical thickness of the atmosphere mist or aerosols (dust particles, plankton and water droplets) to the optical thickness of the atmosphere Standard (molecules) only described the relationship (6).

$$t_R = \frac{m + m_{aero}}{m} \quad \text{................(6)}$$

Where m , m_{aero} vertical optical thickness of the nebula (aerosols) and components of air molecules, respectively. Relationship which describes the optical thickness (optical air mass) is

$$m = \frac{1}{\cos(\theta_s) + 0.15 * (93.885 - \varphi_s)^{-1.253}} \quad \text{............(7)}$$

As well as in the theory of scattering, the coefficient of scattering overall coefficient scattering angular determine how to scattering of light by particles [4], in this research, the Riley scattering used for the gas molecules while Mie scattering is used to molecules aerosol (nebula).
What can be seen is that the total scattering coefficient represents the integration of the angular scattering coefficient all which trends described as (8):

$$\beta = \int \beta(\theta) d\omega \quad \text{......................(8)}$$

And that's where Riley scattering coefficient and total angular gas molecules is given to the relationship (9) (10).

$$\beta_m = \frac{8\pi^3(N^2-1)^2}{3N\lambda^4}\left[\frac{6+3p_n}{6-7p_n}\right] \quad \text{......................(9)}$$

Where n - the refractive index of air (1.0003).
N –Number of particle per size unit ($2.545*10^{25}$ particle /cm^3)

p_n - Polarization coefficient (air 0.0350).
Mie scattering of the nebula can calculated by the equation (10).

$$\beta_p(\theta) = 0.434c(\frac{2\pi}{\lambda})^{v-2}\, 0.5\eta(\theta) \quad \text{......................(10)}$$

Where
c - concentration factor which changes with the disorder $(0.6594T-0.6510)*\ 10^{-16}$
T - disorder.
υ - Junges component equals 4.
η - Mie scattering Limit.
The permeability coefficient resulting from the Riley scattering depending on the optical thickness can be written as
T - disorder.
- Junges vehicle and equal to the number 4.
The permeability coefficient resulting from the Rayleigh scattering depending on the optical thickness can be written as (11).

$$\tau_{Raile} = e^{(-0.008735\lambda)^{-4.08*m}} \quad \text{..................(11)}$$

The scattering coefficient caused by air turbulence is:

$$\tau_{Turbidity\ (aerosols)} = e^{(-\beta\lambda)e^{-\alpha m}} \quad \text{................(12)}$$

Where
α - coefficient of wavelength equals to 1.3.
λ - Wavelength in micro meter units.

And for ozone [11]:

$$\tau_{Ozone} = e^{-k_o \lambda l m} \quad \text{......................(13)}$$

Where
k_o, l represent the amount of ozone in units of centimeter and extinction coefficient of ozone, respectively.
As well as water vapor is given by:

$$\tau_W = e^{(-0.2385 k_{wa,\lambda} w\ m/(1+20.07 k_{wa,\lambda} w\ m)^{0.45})} \quad \text{......................(14)}$$

Where $k_{wa,\lambda}$ - extinction coefficient of water vapor, which depends direct dependence on the wavelength of the light passing through the amount of water vapor.
w - The amount of water vapor in centimeter units.
And for the rest of the various gases that may be called mixed gases, we find that the resulting coefficient of permeability is given to the relationship (11):

$$\tau_{mixed\ gases} = e^{(-1.4 k_{g,\lambda} \lambda m/(1+118.9 k_{g,\lambda} m))^{0.45}} \quad \text{..................(15)}$$

Where
$k_{g,\lambda}$ - extinction coefficient of different gases (depending on the wavelength of the incident light).
The table (1) shows transactions winding down for some components of the atmosphere studied in the research.

Table (1) Transactions subsiding air for some of the components [12]

λnm	kozon	Kwater	Kmixed gases	λnm	Kozon	kwater	Kmixed gases
380	-	-	-	610	0.12	-	-
390	-	-	-	620	0.105	-	-
400	-	-	-	630	0.09	-	-
410	-	-	-	640	0.079	-	-
420	-	-	-	650	0.067	-	-
430	-	-	-	660	0.057	-	-
440	-	-	-	670	0.048	-	-
450	0.003	-	-	680	0.036	-	-
460	0.006	-	-	690	0.028	0.016	-
470	0.009	-	-	700	0.023	0.024	-
480	0.014	-	-	710	0.018	0.0125	-
490	0.021	-	-	720	0.014	1	-
500	0.03	-	-	730	0.011	0.87	-
510	0.04	-	-	740	0.01	0.061	-
520	0.048	-	-	750	0.009	0.001	-
530	0.063	-	-	760	0.007	1e-05	3.0
540	0.075	-	-	770	0.004	1e-05	0.21
550	0.085	-	-	780	-	0.0006	-
560	0.103	-	-				
570	0.12	-	-				
580	0.12	-	-				
590	0.115	-	-				
600	0.125	-	-				

The equation which calculate the amount of solar radiation the total specific area on the earth's surface is the result of the collection of effects absorption and scattering by both types for the various components of air, depending on the position of the sun, which in turn determines the amount of visual thickness as reducing influential on those processes described as.

$$Q = I_o e^{-\tau_{tot} m} \qquad \text{.............(16)}$$

Where τ_{tot} represents the sum of the effects of air permeability of the components mentioned above.

The simulation results

After the application of climate data in the equations to calculating the angle of the fall of the solar radiation (longitude and latitude), as well as the application of data of temperature and relative humidity, water vapor and dust on the equations of permeability, absorption, scattering and visual thickness of air components , initially we found the theoretical values of hours brightness, which contributed to determine the position of the sun where the theoretical values of brightness hours or theoretical time as the follows.

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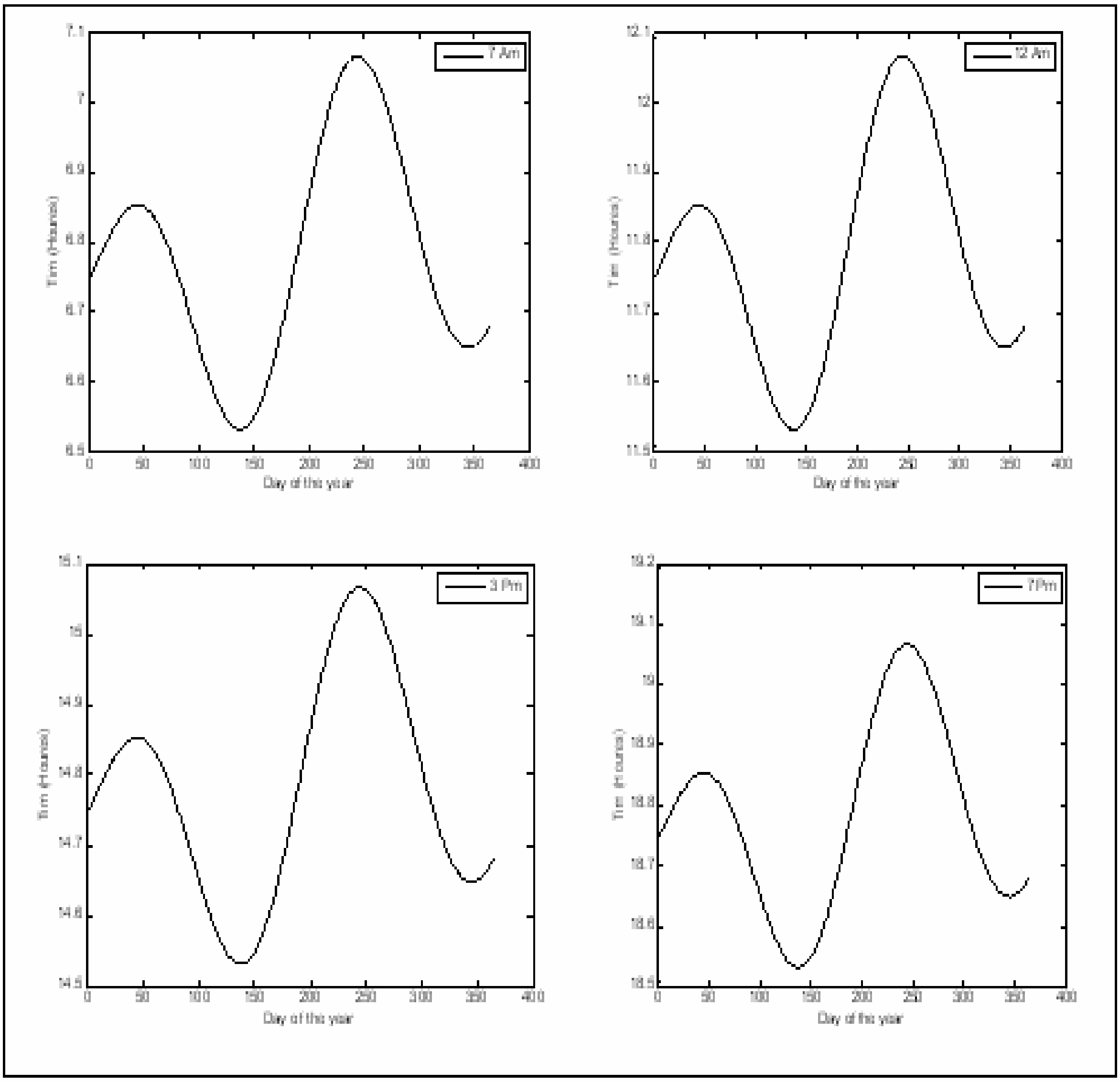

Figure 3 shows the actual change in daylight hours with the theoretical time (7-12 am) and (3-7 pm) for a full year

As shown by the shapes above that all the values of the theoretical brightness hours that the largest possible in the sequence of the incident days in the summer and all of theoretical brightness hours which taken (7Am, 12Am, 3Pm, 7Pm).).
This shows the length of daylight in the summer and the winter palace.
In the other section of the results it has been studied change azimuth of the sun with the daylight hours, as well as the sequence of the day of the year because it has the greatest impact in the optical path length difference and as illustrated by the following formats.

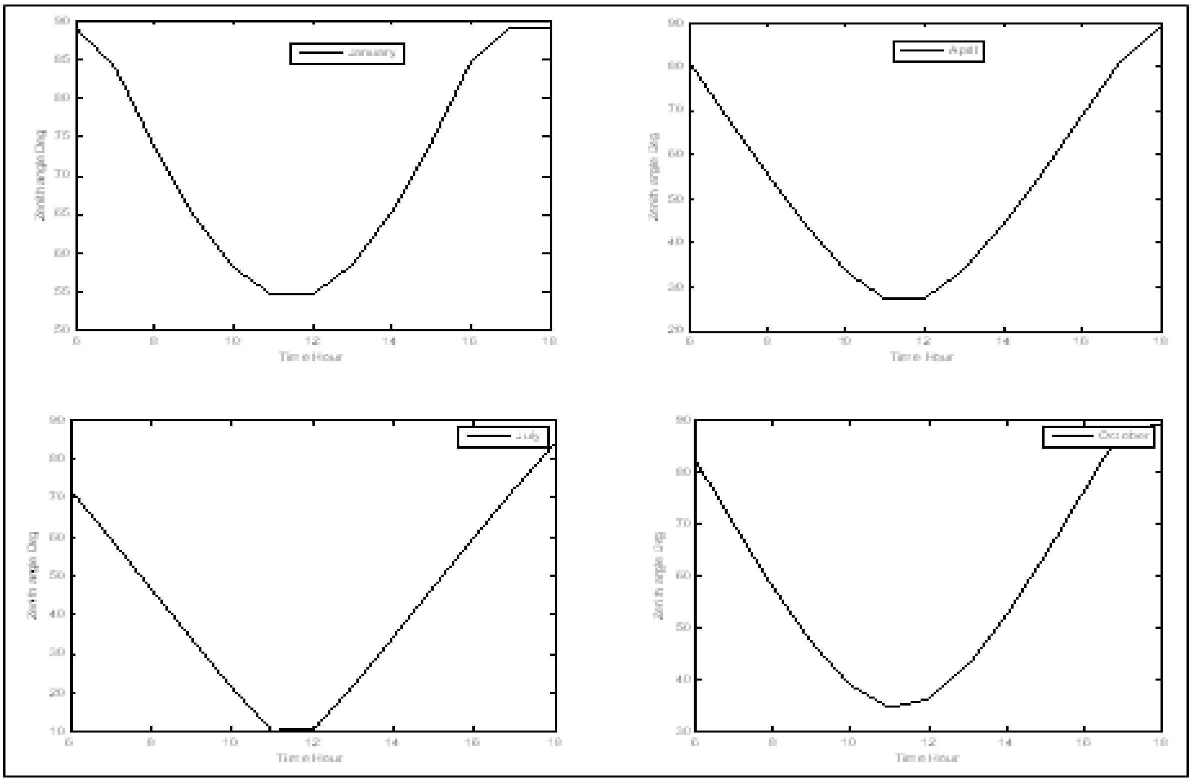

Figure (4) shows the change azimuth with the daylight hours to the four seasons of the year

It is noted that the azimuth changed successively with the change of the sequence of the day (change season) where it is clear that the biggest change or variation values are located in the month of July the range values where from 70 degrees and is approaching to be up to about 10 degrees at noon and thus the length of the optical path will be as small as possible so the losses occurring in the solar radiation energy will be as small as possible in the summer.

Also, the main objective of this research is to calculate the amount of solar energy reaching the site studied was found that the amount of solar energy received per m^2 in Hilla city for one day (day 15) and all the seasons of the year was the values shown in Figure (5), and Table (2) shows the values of total solar radiation incident on the horizontal surface of Hilla city, for a full month, taking into account that the overall rate for the whole month was a very valuable approach to the theoretically calculated values of the middle of the month (15 days).

Table (2) shows the values of total solar radiation incident on the horizontal surface of Hilla city for, the four chapters in units of W / m^2

Time (hour)	January	April	July	October
6:00 AM	0	28.0181	88.0913	0.2087
7:00 AM	0.2411	266.0016	357.7966	110.4213
8:00 AM	84.7463	541.1519	617.5165	358.9061
9:00 AM	278.0296	745.6427	807.2549	565.7452
10:00 AM	436.1827	872.6148	926.8933	692.9176
11:00 AM	519.8379	930.7211	984.5852	742.7358
12:00 PM	525.3639	925.5391	985.437	718.8033
1:00 PM	452.7847	856.5619	929.5184	619.2397
2:00 PM	304.2994	717.3774	811.8415	439.465
3:00 PM	110.0321	499.8321	624.232	194.3934
4:00 PM	1.5696	218.5275	366.1187	10.2428
5:00 PM	0	11.5503	94.2725	0
6:00 PM	0	0	0.0448	0

For comparison, after drawing the values we get:

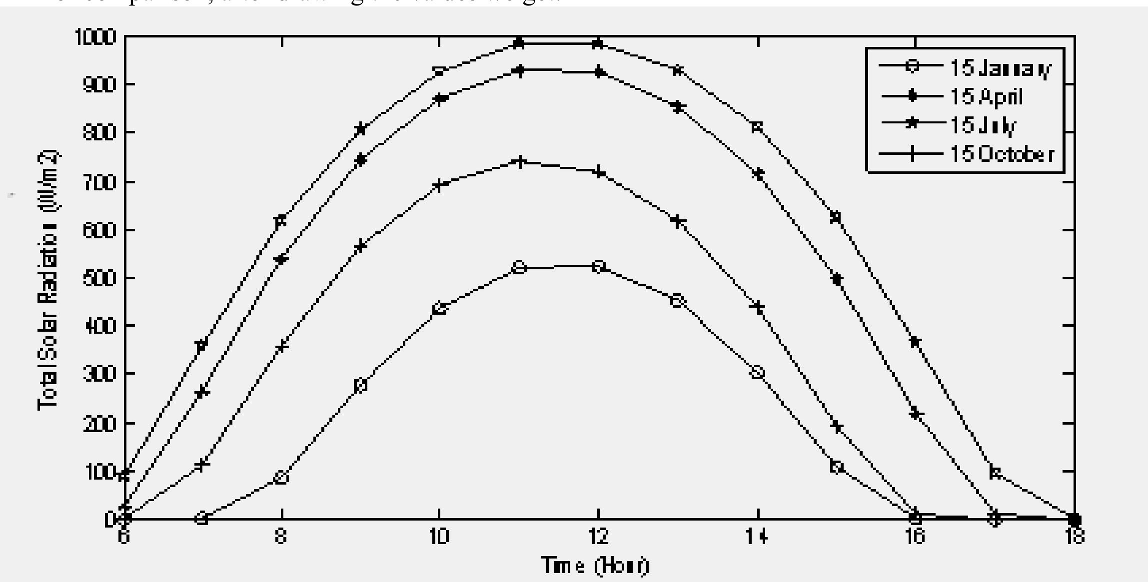

Figure (5) Hour changes the total amount of solar radiation incident on a horizontal surface in units of W / m^2 for each chapter of the year

As is clear from the graph that the values of the amount of solar radiation are less as possible during the first daylight hours (zero when hours rise) in December and is due to the different position of the sun relative to the earth's surface so impact angle of the fall of the sun and thus the amount of radiation received while we find that the greatest values for the amount of radiation occurs at midday (approximately 12-2 pm) and for all the seasons where the solar radiation passing through the atmosphere crossed the shortest way to it while it's longer way at possible in the hours of sunrise and sunset exposing them to the absorption and scattering by components of the atmosphere at those long tracks, as seen through so that the angle of inclination of the sun with a significant and effective impact on the amount of solar radiation falling on a specific area of the earth's surface, as well as when studying the effect of dust, clouds and temperatures it is natural to have influence in the direction of reducing the amount of energy received because it increase the absorption and scattering processes occurring of the solar beam absorption and scattering increasing when the number of particles within the solar beam path increase.

Conclusions

Through this study it've been reached to many conclusions which can be summarized in the following points:

1 - The values of the recipient's total solar radiation on a horizontal surface to a certain area arec influenced by the geographical location and weather conditions of dust, water vapor and clouds.

2 - More wavelengths of solar ray passing through the atmosphere is up to (4-7) microns.

3 - by the results and discussion, it is clear that the effect of clouds are very few compared with the effect of geographical location and concentrations of dust, especially the angle of solar radiation falling.

4 - The above-mentioned equations in the search can be applied for any region of the country of Iraq after the inputing the values of the geographical location and climate data, where values have been compared to the total solar radiation incident with some of the values obtained from some of the sources can not be a process of readings for the country.

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