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Estimation and Simulation of Solar Radiation in Certain Iraqi Governorates

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Abstract: ***In Iraq, the solar radiation is available in huge amounts so it can be regarded as a useful source of energy. Therefore, it is important to recognize its amount and behavior. This paper studied the behavior of extraterrestrial, global, diffused, and beam radiation and compares them with those measured by metrological station. The effect of collector tilt angle is also presented. Results in general showed a good closeness between calculated and measured radiations for almost cases. It is noted that Musul city have the greater ranges of global radiation than Baghdad and Nasiriya while Nasiriya have greater extraterrestrial radiation than Musul and Baghdad, this difference may be caused by environmental effects such as dust, humidity, wind speed and etc. These generalized curves are probably necessary in the design and the prediction of potentiality of any solar system applications at this location.***

Keywords: Solar Radiation, Global radiation, Tilt angle, Beam radiation, Diffused radiation

Nomenclature:

$\bar{H}$	Monthly average daily radiation	[J/m^2-day]	**Subscripts**	
ND	Number of days	[Day]	B	Beam
N	Day length	[hr]	D	Diffuse
K_T	Clearance Parameter	[-]	G	global
a, b	Regression constants	[-]	O	Extraterrestrial
$\bar{n}$	Bright sunshine hours	[J/K]	S	Solar
Greek Symbols		[-]	Z	Zenith
Α	Altitude angle	[-]		
Β	Collector slope angle	[W]		
Γ	Azimuth angle	[Ω]		
Θ	Incidence angle	[K]		
Δ	Angle of declination	[V]		
Φ	Latitude angle			
Ρ	Reflectivity			

1. Introduction

The performance of any solar thermal system depends on the solar radiation available falling on it. Solar radiation is characterized by its variability. Even when abundant, it varies during the day, reaching a maximum at noon when the path length through the atmosphere is the shortest. Unless the collector is continuously turned to face the sun, the sun changing altitude and azimuth will reduce the collected heat below the potential maximum. Hours of day light also vary seasonally, being the shortest in winter when the need for heat is the greatest **[1].** Knowledge on global solar radiation is essential in the prediction, study and design of the economic viability of systems which use solar energy. Information on global solar radiation received at any site (preferably gained over a long period) should be useful not only to the locality where the radiation data is collected but also for the wider world community **[2].** A global study of the world distribution of global solar radiation requires knowledge of the radiation data in various countries and for the purpose of worldwide marketing, the designers and manufacturers of solar equipment will need to know the average global solar radiation available in different and specific regions **[3].**

Among the pioneer work of analyzing hourly global solar radiation data are those carried out by **Whiller [4**] and **Hottel** and **Whiller [5], Liu and Jordan [6], Orgaill and Holland [7],** and **Collares-Pareira** and **Rabel [8].** Recent research works on the estimation of hourly solar radiation have been conducted by many researches around the world. **Al-Sadah et al., [9] and Singh et al., [10]** correlated hourly solar radiation with sunshine hours. **Ahmed and Tiwari [11]** evaluated and compared several hourly solar radiation models. **Gueymard [12]** developed a method for estimating hourly solar radiation from daily solar radiation. **Katiyar et al., [13]** and **Katiyar and Pandey [14]** presented an analysis of hourly solar radiation data and developed new regression constants for estimating the hourly solar radiation on a horizontal surface, which is based on the ASHRAE model **[15]. Chandel** and **Agaerwall [16].**

This paper present the monthly average extraterrestrial, global, diffuse, and beam radiation for some Iraqi governorates (Baghdad, Musul and Nasiriya) one year and make compression between the calculated global radiation with measured radiation (by metrological station) by using simulation computer program. In addition the collector slop (tilt angle) was taken in account and know it's effect. The future scope of improving the present study is characterized by expanding the methodology to simulate sunny and cloudy days and to cover all governorates in the country.

2. Methodology

The location of any point on the earth and it is relation with the sun radiation at any instant may be described by latitude (φ), solar hour angle (ω) and the declination angle (δ) **[17].** Figure (1) shows the sun earth main angles.

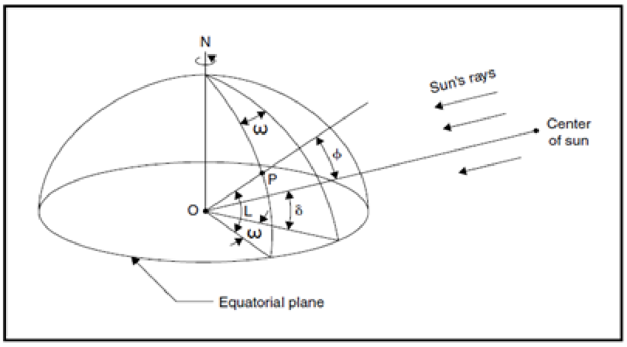

Figure 1: sun-earth main angles **[18]**

Many researchers attempted to establish relationships linking values of radiation (global or diffuse) with metrological parameters like sun shine, cloud cover and precipitation, etc. The mathematical model of solar calculation which used in this paper is based on that found in [18]. This mathematical model is presented in Appendix at the end of the paper.

3. Simulation

The first step of solar radiation estimation was modelling and methodology. The mathematical modelling presents the related formulas that govern the solar radiation. The next step is the simulation program constructed that execute all process that shows the results as fast and efficient as possible. Simulation program was built by using MATLAB in order to process all model of calculation. The inputs of main related parameters such as standard time, latitude angle bright sunshine hours, tilt angle of collector, solar constant, extinction coefficient, and collector thickness must be stated. There are multi-processes carried out to calculate all variables such as number of days, solar time, hour angle, declination angle azimuth angle sunset and sunrise angle, day length each of these variables was related to each other in some way then it used the radiation quantities such as Extraterrestrial, global, diffused, beam radiations and total radiation collected by tilt collector. Necessary loops were made to reveal the desired results. Finally, the results must be displayed. Figure (2) shows the flow chart of simulation program.

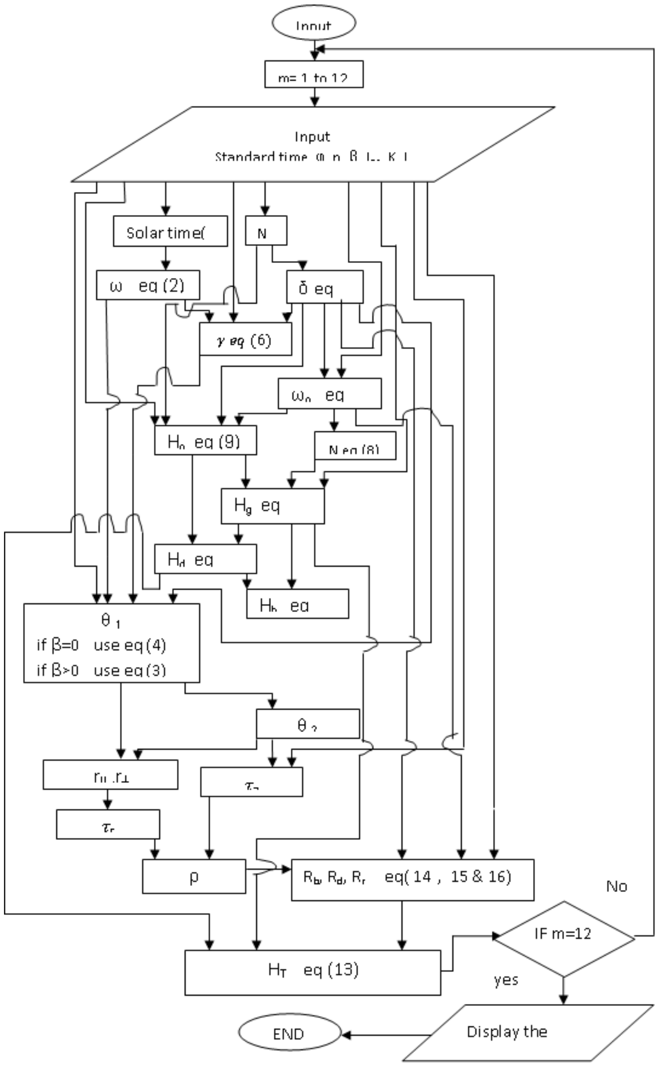

Figure 2: Simulation flow chart

4. Results and Discussion

The results obtained give a clear idea about the behaviour of solar radiation for each month along year. Figure (3) shows the behaviour of extraterrestrial radiation along year, it is clear that all cities (Baghdad, Musul and Nasiriya) have same behaviour but there is a small difference between them. Nasiriya have higher level of extraterrestrial radiation than Baghdad and Musul respectively because it's geographical location. Figure (4) presents the diffused radiation along year. Diffused radiation in Nsiriya was higher than of Baghdad and Musul because it's dusty humid weather. In addition, the diffused radiation in Musul was higher than of Baghdad because it's cloudy weather. Figure (5) shows the global radiation; in general Musul and Baghdad have higher global radiation than Nasiriya. Figure (6) gives an indication about beam radiation, it shows that Nasiriya have lower level of beam radiation than Musul and Baghdad because of the relatively high diffused radiation discussed in figure (4). The effect of collector tilt angle is presented in figure (7). For zero degree tilt angle the radiation will have higher level than another angles, for 45^o tilt angel have lower level of radiation. Also it shows that 90^o tilt angle have approximately same radiation of 0^o. Figure (8), (9) and (10) shows the compression of calculated (by computer program) and measured (by metrological station) solar radiation in Baghdad, Musul and Nasiriya respectively. There a very clear closeness between them. The constructed computer-program used in this study was very helpful in providing immediate and accurate values for the solar components for any site in the country. It can easily be expanded to process many regression models, and hence used for the estimation of Annual average solar radiation.

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Author Profile

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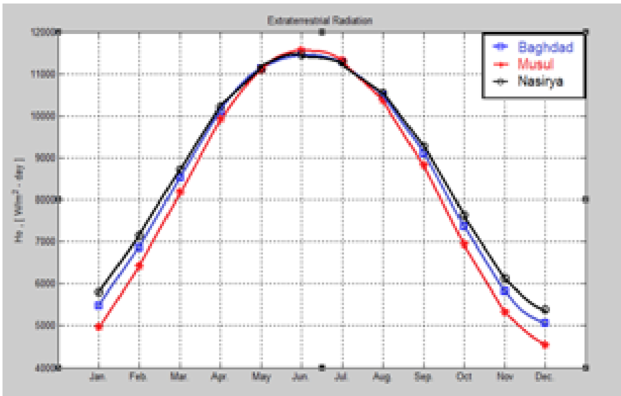

Figure 3: Extraterrestrial radiation for Baghdad, Musul

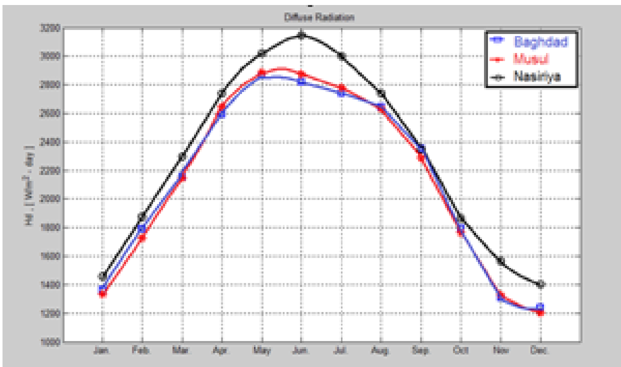

Figure 4: Diffused radiation Baghdad, Musul and Nasiriya

and Nasiriya

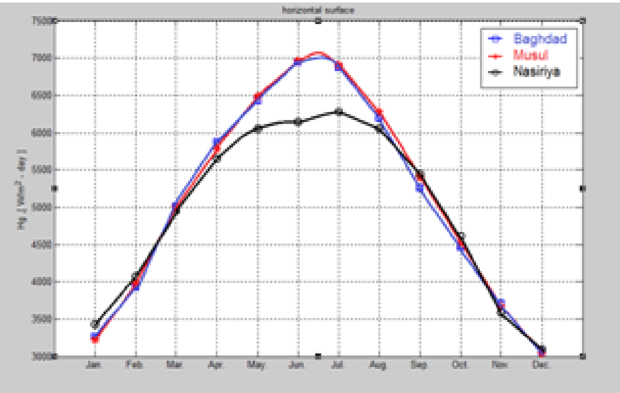

Figure 5: Global radiation Baghdad, Musul and Nasiriya

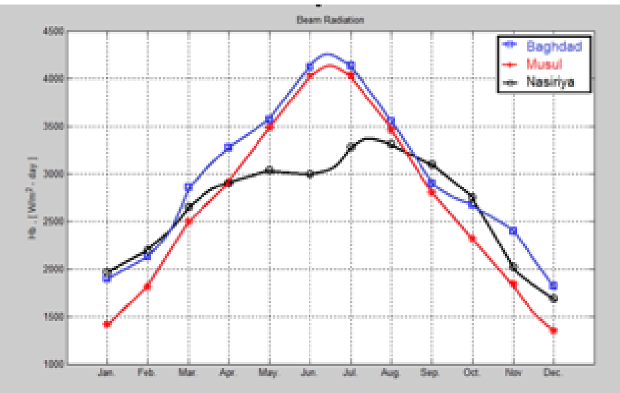

Figure 6: Beam radiation Baghdad, Musul and Nasiriya

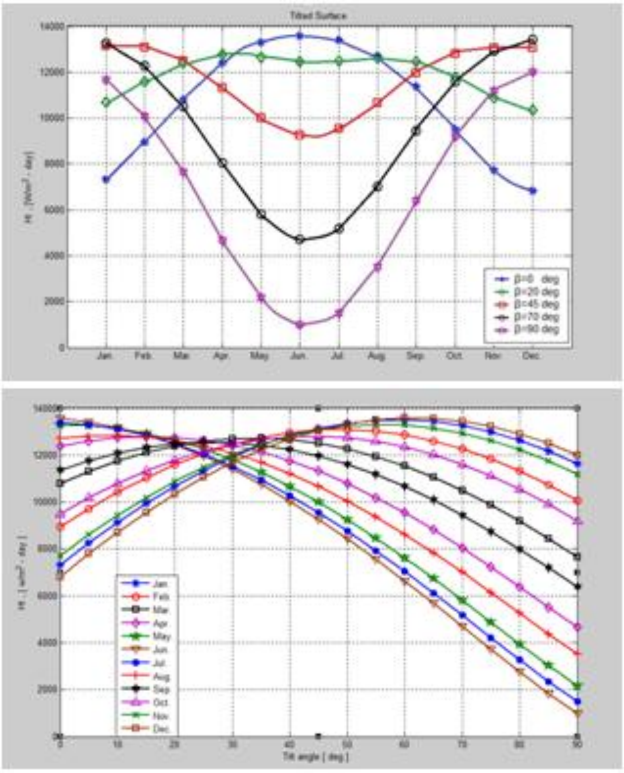

Figure 7: Tilt angle variation

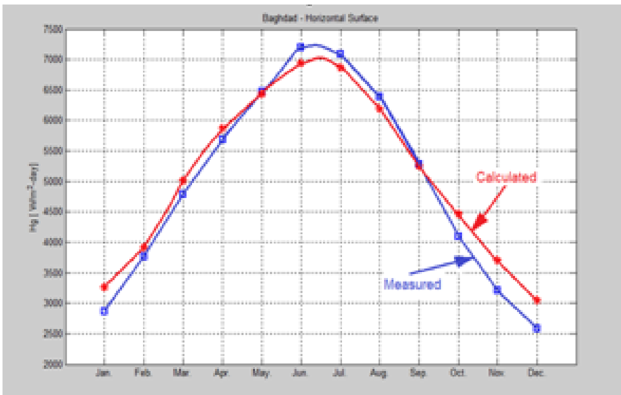

Figure 8: Comparison between calculated and measured radiation for Baghdad

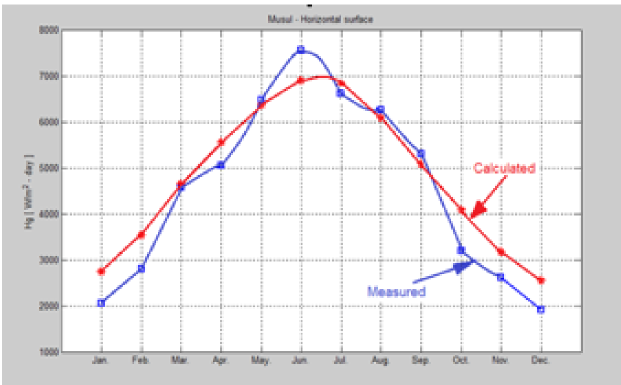

Figure 9: Comparison between calculated and measured radiation for Musul

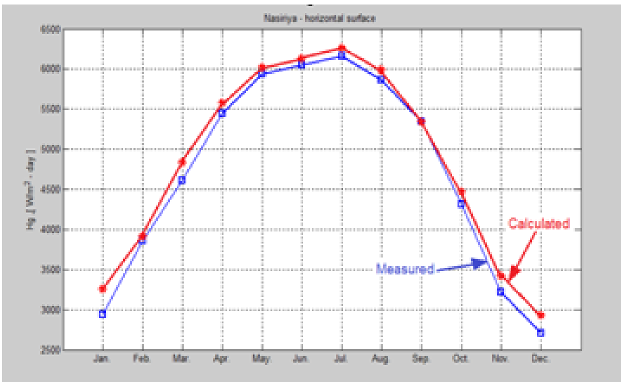

Figure 10: Comparison between calculated and measured radiation for Nasiriya

Appendix

2-1-1-Latitude angle (φ):

It is the angular location north or south of the equator, north positive,

$-90 \leq \varphi \leq 90$

$$\delta = 23.45 * \sin[\frac{360}{370}(ND - 80)] \quad (1)$$

Where ND is the No. of days

$$\omega = 15*[\text{solar time} - 12] \quad (2)$$

$$\cos(\theta) = \sin(\delta)\sin\varphi\cos(\beta) - \sin(\delta)\cos(\varphi)\sin(\beta)\cos(\gamma) + \cos(\delta)\cos(\varphi)\cos(\beta)\cos(\omega) + \cos(\delta)\sin(\varphi)\sin(\beta)\cos(\gamma)\cos(\omega) + \cos(\delta)\sin(\beta)\sin(\gamma)\sin(\omega) \quad (3)$$

For horizontal surface β=0. Thus,

$$\cos(\theta) = \cos(\delta)\cos(\varphi)\cos(\omega) + \sin(\delta)\sin(\varphi) \quad (4)$$

$$\sin(\alpha) = \cos(\delta)\cos(\varphi)\cos(\omega) + \sin(\delta)\sin(\varphi) \quad (5)$$

$$\tan(\gamma_s) = \frac{\sin(\omega)}{\sin(\varphi)*\cos(\omega) - \cos(\varphi)*\tan(\delta)} \quad (6)$$

$$\omega_o = \cos^{-1}[-\tan(\varphi)\tan(\delta)] \quad (7)$$

$$\text{It N} = \frac{2}{15}\cos^{-1}[-\tan(\varphi)\tan(\delta)] \quad (8)$$

$$H_o(J/m^2) = \frac{86400}{\pi} Isc\left[1 + 0.033\cos\left(\frac{360\ ND}{365}\right)\right] * (\cos\varphi\cos\delta\sin\omega_o + \omega_o * \sin\varphi\sin\delta) \quad (9)$$

$$\frac{\overline{H_g}}{H_o} = a + b\left(\frac{\overline{n}}{\overline{N}}\right) \quad (10)$$

a = 0.25 and b = 0.5 are recommended and applicable anywhere in the world **[20].**

$$H_d = H_g(1.354 - 1.57\overline{K_T}) \quad (11)$$

$$H_b = H_g - H_d \quad (12)$$

$$\frac{H_T}{H_g} = \left(1 - \frac{H_d}{H_g}\right)R_b + \frac{H_d}{H_g}R_d + R_r \quad (13)$$

For south facing surface, $\gamma = 0^o$

$$R_b = \frac{\omega_{st}\sin\delta\sin(\emptyset-\beta) + \cos\delta\cos\omega_{st}\cos(\emptyset-\beta)}{\omega_s\sin\delta\sin\emptyset + \cos\delta\cos\omega_s\cos\emptyset} \quad (14)$$

$$R_d = \frac{1+\cos\beta}{2} \quad (15)$$

$$R_r = \rho\left(\frac{1-\cos\beta}{2}\right) \quad (16)$$