Determination And Analysis Of Total Solar Spectral Radiation Falling On Horizontal Surface

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Abstract:

The knowledge of the amount of total solar spectral irradiance (TSSI) falling on horizontal surface is essential requirements for designing solar energy systems, especially for photovoltaic system. The main purpose of this paper is to study and analyze the total spectral irradiance in Baghdad (Lat.33º ٢١َ N 44º ١٤ً E Long . and 34m above MSL). Measurements were made by Epply spectral pyranometer using Schott filters WG7, OG1, RG2 and RG8 with the wavelength intervals [(280-2800), (530-2800),(630-2800) and (695-2800)]nm, respectively. The study include the monthly average of the hour, and daily solar spectral irradiance and the correlation between the solar altitude and sunshine duration with different solar spectral irradiance.

حساب وتحليل الطيف الشمسي الكلي الساقط على السطح الأفقي

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ملخص البحث:

أن معرفة الحزم الطيفية للإشعاع الشمسي الساقط على السطح الأفقي مهمة جدا في معظم تطبيقات الطاقة الشمسية وخاصة الخلايا الفوتوفولتائية. لذا تم في هذا البحث دراسة

وتحليل الحزم الطيفية للإشعاع الشمسي لمدينة بغداد الواقعة على خط طولَ ١٤ ٤٤° وخط عرض ٢١ ٣٣° وعلى ارتفاع m ٣٤ فوق مستوى سطح البحر والمقاسة بواسطة (Epply Pyranometer) باستخدام مرشحات شوت (RG8,RG2,OG1,WG7) ضمن الحزم الموجية (280-2800) و (٥٣٠-٢٨٠٠)و(٦٣٠-٢٨٠٠) و (٦٩٥-٢٨٠٠) نانومتر وعلى التوالي تضمنت الدراسة دراسة التغيرات للمعدلات الساعية واليومية الشهرية للحزم الطيفية والعلاقات الرياضية بين زوايا ارتفاع الشمس وساعات الشروق الشمسي مع مختلف الحزم الطيفية.

Introduction

Quantitative data on available solar spectral irradiance received at the earth surface is an essential input parameter for the design of solar energy conversion systems, and for selecting optimum sites of solar power stations and computing the efficiency of various system. Furthermore, for feasibility studies for possible uses of solar energy[Duffie et al (1974)]. Solar spectral radiation data on ground level depends on several parameters. They are: geometry of the site (altitude, latitude, longitude, sun-earth distance , time of the day, seasons of the year, cloudiness of the atmospheric, slope of the collector surface or photovoltaic panels and atmospheric attenuation due to water vapor, Ozone, Carbon dioxide and aerosols). A study and analysis of total solar spectral irradiance have been carried by [Zain et al (1987),Abdul Wahab(1988),Spence et al(1983),Sadler(1976), Abdul Wahab et al(1994),Shaltout(2001)], analysis and estimation of solar spectral irradiance in Iraq have been carried out by [Musa et al (1987)and Ahmed et al (1999)]. The data used in this study were based on long period of one year measurements made at solar energy research center in Baghdad. The aim of this study is to analyze the monthly average , seasonal variation of total solar spectral radiation falling on horizontal surface and their fluctuations with solar altitude and sunshine duration.

Experimental Design:

The Schott filters are used in the present study to measure the total spectral solar irradiance (TSSI) at Baghdad. The Schott filter are broad band pass filters with well defined short wave length cutoffs. The wavelength ranges are (280-2800)nm for WG7 filter, (530-2800)nm for OG1 filter, (630-2800)nm for RG2 filter and (695-2800)nm for RG8 filter. Data measurements were made by four Epply precision spectral pyranometer using Schott filter glass WG7(280), OG1(530), RG2(630) and RG8(695) under all sky conditions and the output was recorded by an Epply digetic integrator, the hourly data were recorded between the hours (05.00-19.00) in summer time and between (07.00-17.00) in winter time.

Theory:

The solar altitude (h) in degree is determined by (Ahmed 2002):

$$h=\sin^{-1}(\sin\Phi\sin\delta+\cos\Phi\cos\delta\cos w)\ldots\ldots\ldots\ldots(1)$$

Where Φ is latitude of location which is equal to 33º ٢١´ for Baghdad city.

δ- is declination angle of the sun which is determined from:

$$\delta=23.45\sin[360/365*(dn+284)]\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where dn day number of the year.

W- hour angle which is determined from this equation:

$$W=360/24*(12-t)$$

Where t is the time in hour.

The hourly extraterrestrial radiation for each month of year is calculated from the equation (Iqbal 1983):

$$I_o]^{t2}=I_{sc}E_o\{\sin\delta\sin\Phi(t_1-t_2)+(12/\Pi)\cos\Phi\cos\delta[\sin(15t_1)-\sin(15t_2)]\ldots\ldots(3)$$

Where I_o is hourly extraterrestrial radiation.

I_{sc}- is solar constant which is equal to 1367 w/m^2.

E_{o-} is correction factor of the earth and is equal $(ro/r)^2$

where ro is mean sun-earth distance.

r- is sun-earth distance.

t_1,t_2- is the time of day in hour.

The day length (N_d)in hour is determined by (Iqbal 1983):

$$N_d=2/15 \cos^{-1} (-\tan \delta \tan \Phi)\text{……..(4)}$$

Data Analysis and Discussion:

1-Variations of total solar spectral irradiance:

The data used in this paper were obtained from hourly measurements of 360 days. The mean hourly values of (TSSI)for the monthly of January, April, July, and October are shown in figure(1). These months are considered to represent the winter, spring, summer and autumn seasons, respectively.

From figure(1), it can be seen that the maximum amounts of(TSSI) are received in summer for all filters and minimum in winter. The maximum values of(TSSI) at solar noon time reaches to 842w/m^2, 650w/m^2, 522w/m^2 and 405w/m^2 for filters WG7, OG1, RG2 and RG8, respectively. The mean daily values of (TSSI) are plotted in figure (2).The maximum mean daily values of (TSSI) for all filters are received in June which is equal to 7313w/m^2, 5666w/m^2, 4582w/m^2 and 3570w/m^2 for filters WG7, OG1, RG2 and RG8, respectively.

2- Correlation between (TSSI) with solar altitude and sun shine duration:

The monthly average of hourly solar spectral irradiance with solar altitude (h) and sun shine duration (n/N_d) are correlated .Figure (3,4) explain the liner correlation between(TSSI) with (h) and (n/N_d), eight good linear correlations are deduced with high correlation coefficient (C.C).The linear regression techniques using the relation :

$$Y=Ax+B$$

The equations deduced and its correlation coefficient for all filters are explained in table (1).

Table (1): the fitted first order equations of mean hourly(TSSI) as a function of solar altitude(h)and sun shine duration (n/N_d).

The fitted equation	No.of equ.	Corr.Coff.
Ih_{280} =9.0083*h+145.29	1	0.9606
Ih_{530} =6.9356*h+114.21	2	0.961
Ih_{630}=5.4791*h+98.166	3	0.9604
Ih_{695} =4.3071*h+74.507	4	0.9611
Ih_{280} =1128.6*(n/N_d)-187.34	5	0.6328
Ih_{530} =868.3*(n/N_d)-141.43	6	0.6322
Ih_{630} =686.76*(n/N_d)-104.41	7	0.6333
Ih_{695} =539.69*(n/N_d)-84.601	8	0.6334

The deduced equations are used to calculate the root mean square error (RMSE), mean bias error (MBE), standard deviation (S.D) and coefficient of variation (C.V) the result of this are shown in table (2).

Table (2): Explain the (RMSE), (MBE), (S.D) and (C.V) for all deduced equations.

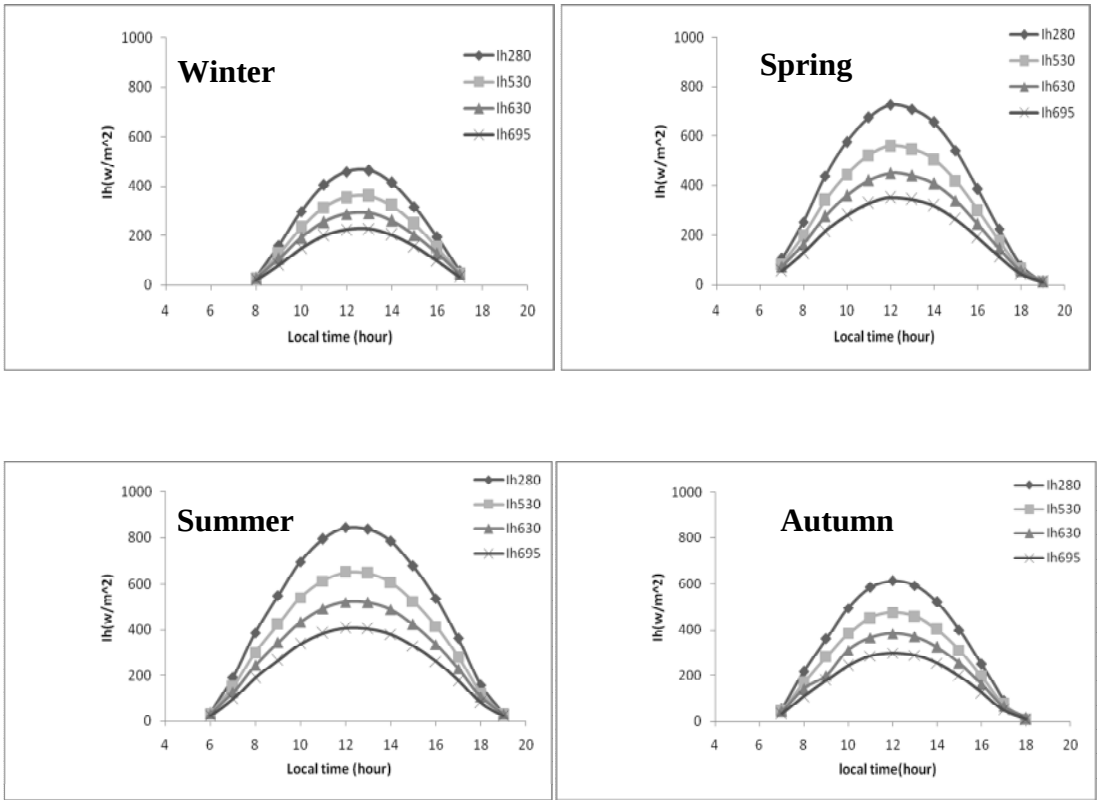
No.of eq.	RMSE	MBE	S.D	C.V
1	0.049	0.0036	155	0.23
2	0.048	0.0034	94	0.27
3	0.049	0.0035	119	0.27
4	0.048	0.0034	71	0.23
5	0.1525	0.0228	8.6	0.017
6	0.1516	0.0226	6.63	0.017
7	0.063	0.246	5.24	0.0167
8	0.149	0.022	4.121	0.0169

The equations deduced from this study are very useful to estimate the (TSSI) values for all filters when there is no instrument which are used to measure(TSSI).

These equations are used to calculate the (TSSI) for all filters. The values of (TSSI) obtained by using these equations are compared with measured values as shown in figure (5) which explain that there is no big difference between measured values (Ih)m and calculated values by using equations (1,2,3,4) but there is small difference from the values of equations (5,6,7,8).

Conclusions:

1- The annual variation of total solar spectral irradiance for all filters show similar characteristic changes.
2- The maximum amounts of mean hourly total spectral solar irradiance for all filters are received in summer and minimum in winter.
3- The maximum mean daily values of total spectral solar irradiance for all filters are recorded in June.
4- Eight equations with high correlation coefficient deduced between (total solar spectral irradiance) with solar altitude and sun shine duration.



Fig(1): Mean hourly variation of (TSSI) for all filters.

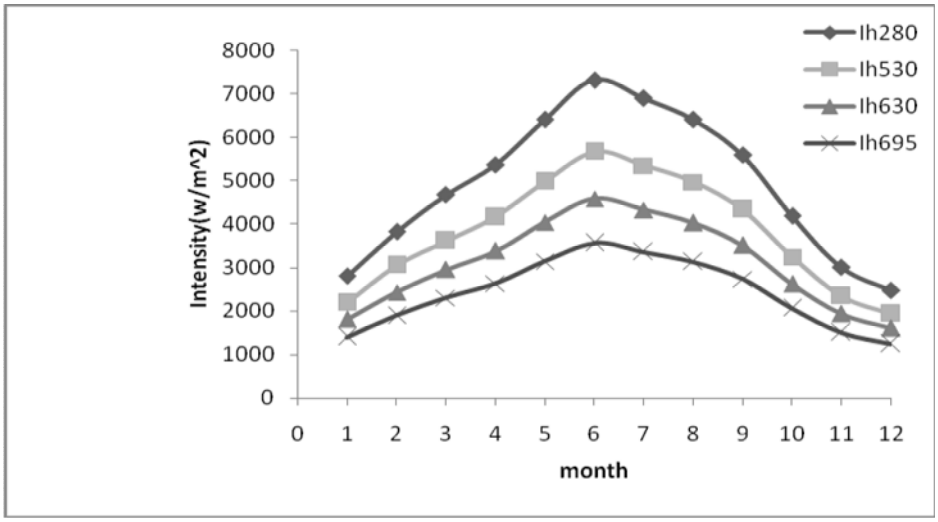
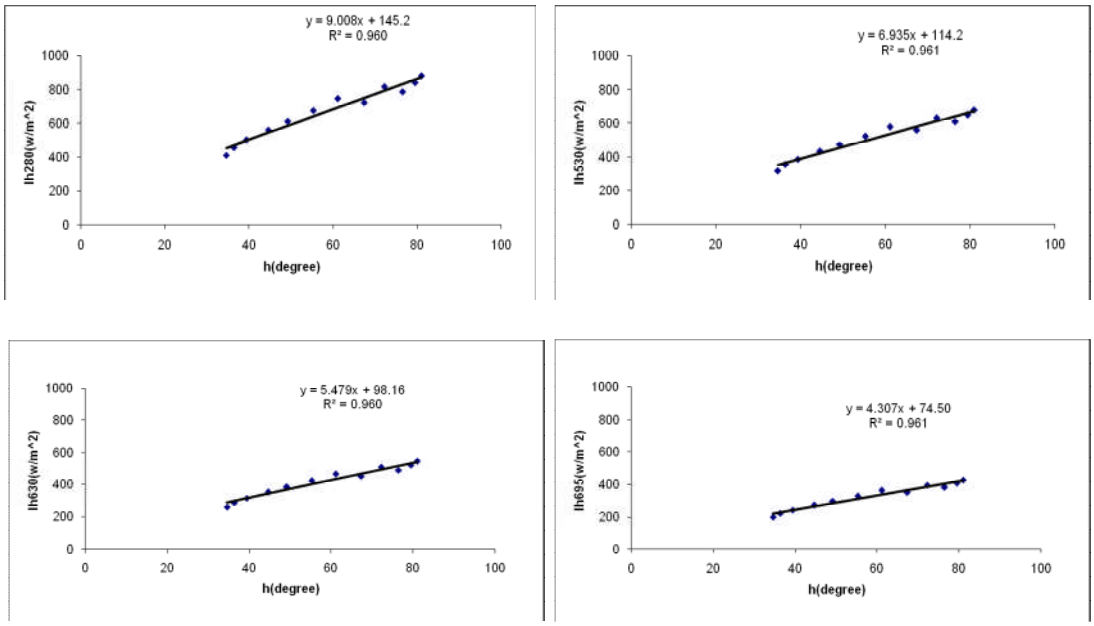
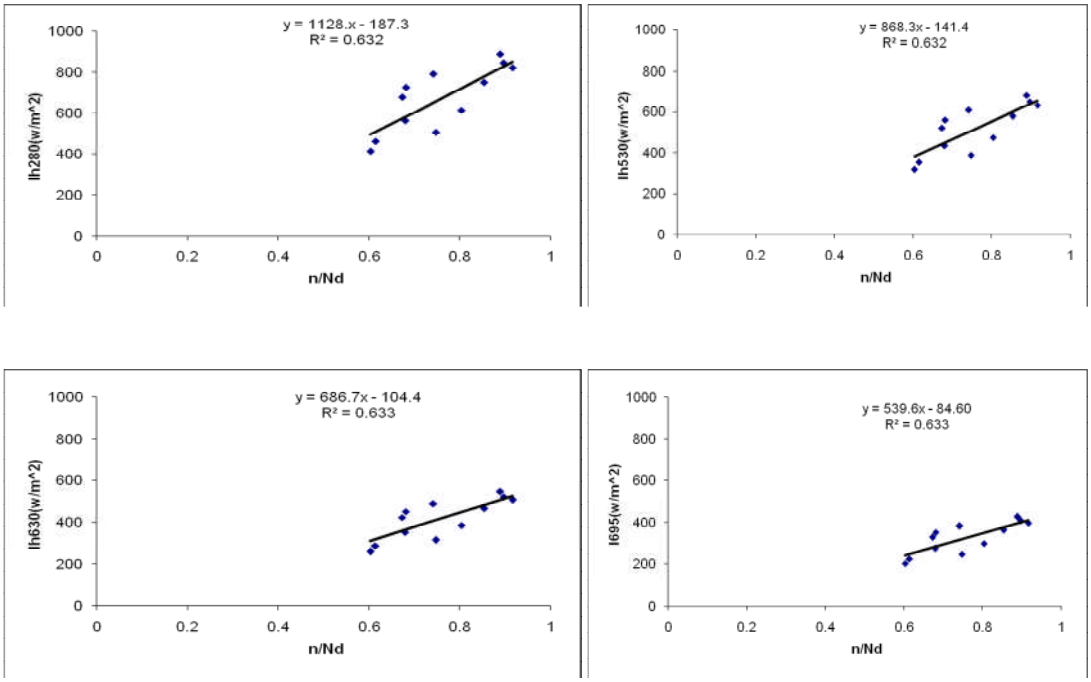


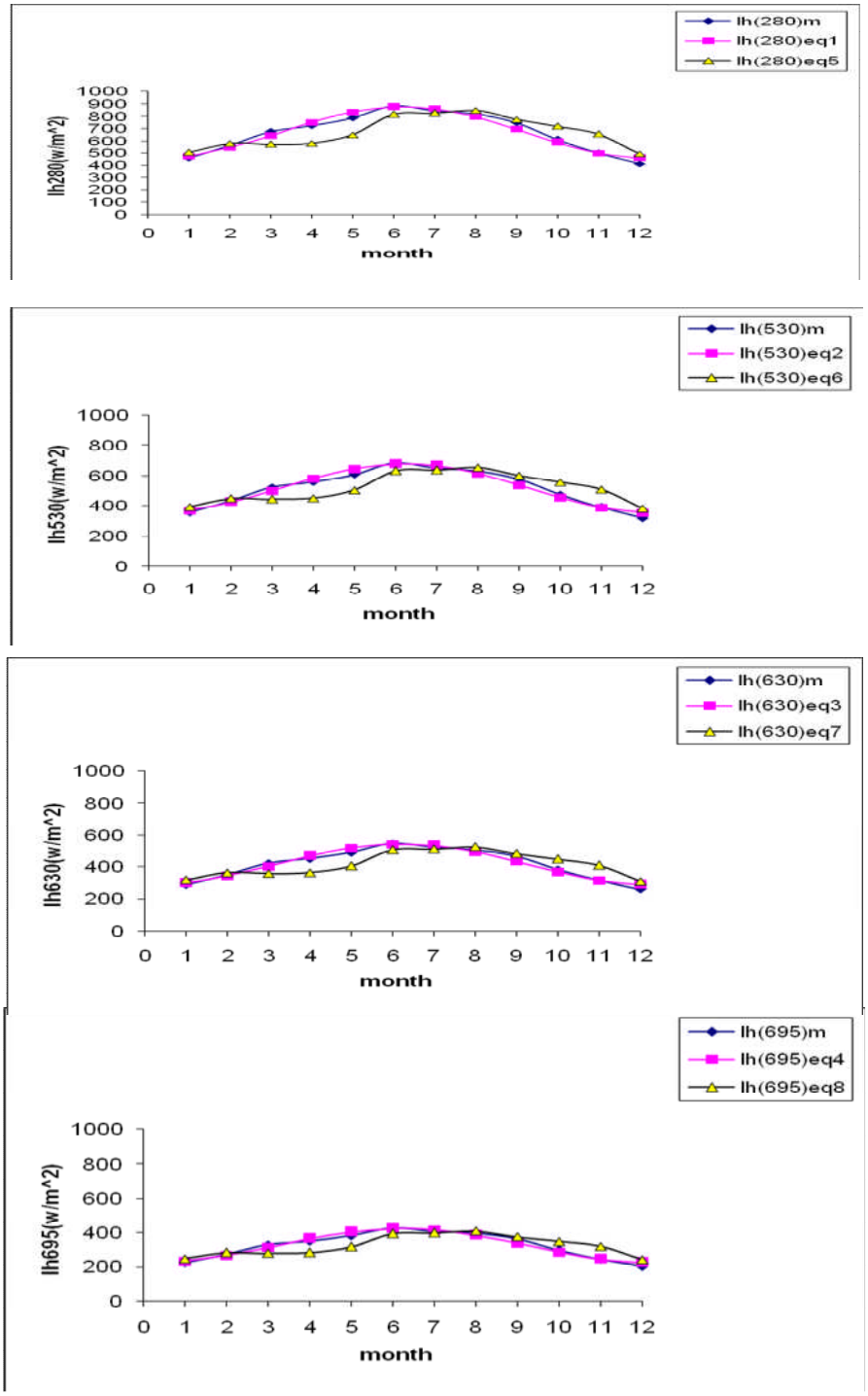
Fig (2):Mean daily variation of (TSSI) for all filters.



Fig(3):The correlations between (TSSI)and solar altitude(h)for all filters.



Fig(4):The correlations between (TSSI)and sun shine duration (n/N_d) for all filters.



Fig(5):The compare measured values of (TSSI)with calculated values.

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