TOTAL GLOBAL AND DIFFUSE SOLAR RADIATION FOR UPPER SINDH, PAKISTAN

M. Akhlaque Ahmed[1], Firoz Ahmad[2] and *M. Wasim Akhtar[3]
[1]Basic and Applied Science, Sir Syed University of Engineering and Technology, Karachi, Pakistan
[2]Energy and Environment Research Group, Department of Physics, University of Karachi, Karachi, Pakistan
[3]Usman Institute of Technology, Karachi, Pakistan

Abstract

Global and diffuse solar radiation studies have been carried out for upper Sindh (Jacobabad) to assess the applicability of solar energy utilization for these areas. The global and diffuse solar radiation was carried out using sunshine hour data. The result obtained shows the variation of direct and diffuse component of solar radiation in summer and winter months. In Jacobabad areas the diffuse radiations is maximum during the month of July and August and minimum during the months of November, December and January. The cloudiness index K_T values indicate the clear sky in the month of January to June and September to December for Jacobabad. From the studies it has been found that with the exception of monsoon months July and August solar energy can be utilized throughout the year for Jacobabad.

Keywords: Solar energy utilization for Jacobabad, Global and diffuse solar radiation for upper Sindh.

INTRODUCTION:

The energy requirement in the world is increasing due to rapid industrialization. The fossil fuel which is the main source of energy supply is depleting day by day. The alternate energy resources (solar and wind) are the solution of this problem. China, India has already developed their alternate energy resources to cop with the energy problem. For a country like Pakistan, the economical and efficient application of solar energy seems inevitable because of abundant sunshine available throughout the year (Ahmad, Firoz *et al*, 1981). The measurement equipment involved in this process are not available in Pakistan and in many countries.

Therefore, it is rather important to develop method to estimate the global and diffuse solar radiation using climatological parameters because detail information about the availability of solar radiation on horizontal surface is very essential for the design and study of solar energy convention system. Several empirical formula have been developed to calculate the global and diffuse solar radiation using various parameters (Ahmad Firoz and Ulfat. 2004). These parameters includes i) The sunshine hours ii) the relative humidity iii) The declination angle iv) the latitude and others. Global solar radiations in Pakistan are measured at six stations namely Karachi, Lahore, Multan, Quetta and Islamabad and Hyderabad. In this work the diffuse and Global solar radiation has been calculated for Jacobabad using sunshine hour data.

The Jacobabad city has an area of 5279 sq. Km. it is located at latitude 28.28 N and Longitude 68.43 E. The population of Jacobabad is 14 million people.

*Corresponding author: drwakhtar@yahoo.com

It is the hottest city of Sindh where in summer the temperature goes up to 50 ^{o}C.

This temperature is very much desirable for thermal application. This whole work will play a very essential role in the city to cop with the energy crises and will set a very strong platform for the planners to utilize the solar energy potential for Jacobabad.

METHODOLOGY:

Extraterrestrial Radiation on a horizontal Surface.

The solar radiation out side the atmosphere incident on a horizontal surface is given by the following expression.

$H_0 = 24/\pi \; Isc \; ([1+0.033 \cos (360n/365]) \; [\cos\Phi \cos\delta \sin Ws + 2\pi \; Ws/360 \sin\Phi \sin\delta]$ (1)

H_0 is the extraterrestrial insulation on horizontal surface where Isc is the solar constants, Φ the latitude, δ the solar declination,
Ws is the sunset hour angle, N day length (= 2/15 Ws).
In equation (1)

$\delta = 23.45 \sin \{ 360x \; 248 + n/365\}$ (2)

and $\cos Ws = -\tan\theta \tan\delta$ (3)

THE GLOBAL RADIATION AT HORIZONTAL SURFACE:

The monthly global solar radiation H/H_0 falling on a horizontal surface at particular location is given as below

$H/H_0 = a + b\,(n/N)$ (4)

where H is the monthly average daily global solar radiation falling on a horizontal surface at a particular

location, H_0 the monthly mean daily radiation on a horizontal surface in the absence of atmosphere, n the monthly mean daily number of observed sunshine hours, N the monthly mean value of day length at a particular location and "a", "b" the climatologically determined regression constant.

In equation (4) n/N is often called the percentage of possible sunshine hour (Black, Bonython and Prescett, 1954).

Regression coefficients "a" and "b" have been obtained from the relationship given by (Tiwari & Sangeeta 1977) and also confirmed by Frere *et al*. method (Frere *et al*. 1980) and (Tiwari G.N and Suleja, Sangeeta. 1977). The relationships are

$$a=-0.110+0.235\cos\Phi +0.323\ (n/N) \quad (5)$$

$$b=1.449-0.553\cos\Phi -0.694\ (n/N) \quad (6)$$

We indicate that in literature there are other methods to evaluate these constants such as (Ulfat *et al*. 2005).

Prediction of Diffuse Solar Radiation (H_d)

The diffuse solar radiation H_d can be estimated by an empirical formula which correlates the diffuse solar radiation component H_d to the daily total radiation H. The correlation equation widely used was developed by Page and Liu and Jordan (Page, Jk 1964),

$$H_d/H = 1.00-1.13\ K_T \text{ (page, JK 1964)} \quad (7)$$

$$H_d/H = 1.390-4.027\ K_T +5.53\ (K_T)^2 -3.108\ (K_T)^3 \text{ (Liu \& Jordan)} \quad (8)$$

where H_d is the monthly mean of the daily Diffuse solar radiation and H is the daily total solar radiation and K_T is the clearness index. (Duffie and Beckman 1991, Frere *et al*. 1980).

$$K_T=H/H_0 \quad (9)$$

Table 1. Input Parameters of Monthly Average Solar Radiation for Jacobabad, Sindh

Months	n Monthly mean sunshine	N Monthly average day light length	n/N Percentage of possible sunshines hours
January	7.6	10.42	0.73
February	8.5	11.04	0.77
March	8.7	11.82	0.74
April	10	12.67	0.78
May	10.3	13.40	0.76
June	10	13.76	0.73
July	9.7	13.60	0.68
August	8.5	12.99	0.65
September	9.6	12.15	0.79
October	9.4	11.30	0.83
November	8.9	10.58	0.84
December	7.0	10.24	0.68

Table 2. Solar Radiation for Jacobabad, Sindh

Month	Ho	H	K_T = H/Ho	Hd/H LJ	Hd/H page	Hd Page	Hd LJ	D= (Hd+Hd)/2	D/H	D/Ho
January	23.16	14.82	0.64	0.22	0.27	4.0	3.26	3.63	0.24	0.16
Februar	27.33	18.03	0.66	0.23	0.25	4.50	4.14	4.32	0.23	0.16
March	32.77	21.30	0.65	0.25	0.26	5.53	5.32	5.43	0.25	0.16
April	37.43	24.70	0.66	0.24	0.25	6.17	5.9	6.03	0.24	0.16
May	43.24	28.53	0.66	0.24	0.25	7.13	6.8	6.96	0.24	0.16
June	41.05	26.27	0.64	0.21	0.27	7.0	5.5	6.30	0.24	0.15
July	40.52	25.12	0.62	0.27	0.29	7.2	6.7	6.90	0.27	0.17
August	38.37	23.65	0.60	0.31	0.32	7.36	7.1	7.23	0.31	0.18
September	34.32	22.65	0.66	0.24	0.25	5.6	5.4	5.5	0.24	0.16
October	30.94	21.03	0.68	0.23	0.23	4.8	5.06	4.9	0.23	0.16
November	23.96	16.53	0.69	0.21	0.22	3.6	3.4	3.5	0.21	0.15
December	21.64	13.41	0.62	0.27	0.29	3.8	3.6	3.7	0.28	0.17

RESULTS

The monthly mean sunshine hour and day length is sown in table 1. The sunshine duration of Jacobabad is between 75% to 80% through out the year. Using these parameters the regression constant 'a' and 'b' are evaluated.

The value of H, K_T and H_d for Jacobabad is estimated by Liue and Jordan and Page method as no station in Pakistan reports diffuse solar radiations. From the calculated result it appears that the contribution of diffuse solar radiation is very very low through out the year. In monsoon months the contribution of diffuse radiation is below 20%.

The availability of direct radiation is therefore very encouraging from utilization point of view. The transmission of the H_d from extraterrestrial radiation is only about 15% which rises to 18% in the month of August. From the observation of clearness index and ratio of diffuse to global, we conclude that presence of clouds is very rare even in monsoon months. This is the favorable condition for solar energy utilization. Fig (1) represents the plots of Extraterrestrial, total, direct and diffuse solar radiation at Jacobabad. In the month of May there appears a sharp rise in (H) and so in beam radiation H_b and diffuse radiation is not more than 30%.

Fig (2) shows the behavior of cloudiness index K_T ratio of diffuse to total radiation and diffuse to extraterrestrial radiation. The dip in the value of K_T in the month of August is accordance with the high value of D/H for the same month. The sky appears clear during the winter months when solar radiation is in demand for utilization purpose.

Atmosphere clearness is indicated by fraction of extraterrestrial radiation that reaches the earth surface as global solar radiation K_T the clearness index is the measures of the degree of clearness of the sky. It is given by

$$K_T=H/H_0 \quad (10)$$

K_T is clearness index, H the global solar radiation, H_0 the extraterrestrial insulation.

From the estimated value of H for Jacobabad the clearness index K_T is calculated from equation (10). It is encouraging to note that the sky over Jacobabad is very clear almost through out the year except in the month of August when K_T = 60%.

Table 3 shows the statistical distribution of Global solar radiation for Jacobabad which indicates that the availability of global solar radiation at Jacobabad is about 70% in winter and in summer months and during monsoon period it is about 61%.

Table 3. Statistical Data of Global Solar Radiation

January --- April	Above 65 perecnt
May ------ June	Above 65 percent
July ----August(monsoon)	Above 61 percent
September ---- December	Above 66 percent

Fig 3 exhibits the trend of variation of direct and diffuse solar radiation. The maxima of direct radiation for the month of April, May and June are quit appreciable. Only in the month of August the diffuse radiation is maximum which is not more than 30% even in worst sky condition. This is confirmed by the low value of K_T and high value of H_d/H. The percentage of diffuse radiation contribution to global radiation is low during winder months. In winter the sky remains bright and clear.

DISCUSSION

The present studies indicated that solar energy utilization

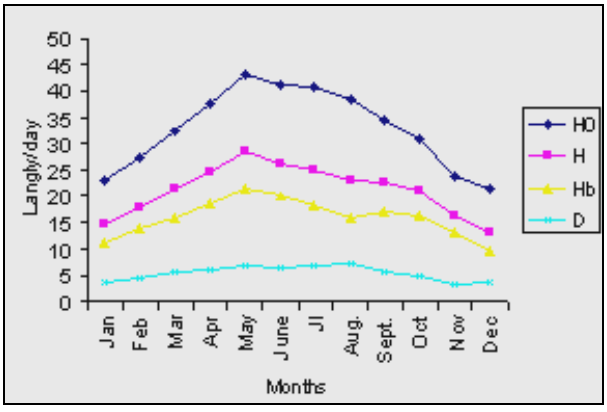

Fig. 1. A Plot of monthly variation of extraterrestrial, total, direct and diffuse radiation for Jacobabad, Sindh, Pakistan

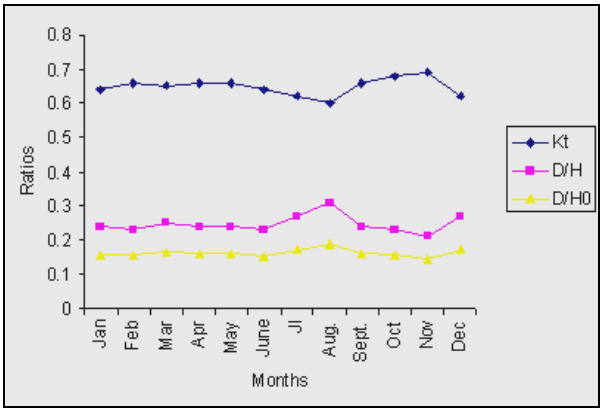

Fig. 2. Shows the behaviour of the cloudiness index Kt, D/H and D/H0 during the year for Jacobabad, Sindh, Pakistan.

has bright prospect in Jacobabad, Sindh, Pakistan. The estimated results of global and diffuse solar radiation reveals that solar radiation can be very efficiently used to compensate the energy shortage in Jacobabad. For the estimation of diffuse radiation Page and Liu and Jordan method are in very good agreement. Due to non-availability of the experimental date for global and diffuse solar radiation for Jacobabad, Sindh, the estimation has been made employing sunshine hour of the location. The Angstrom model and Page, and Liu and Jordan model for Global and diffuse solar radiation for Jacobabad Sindh, serves the purpose very effectively.

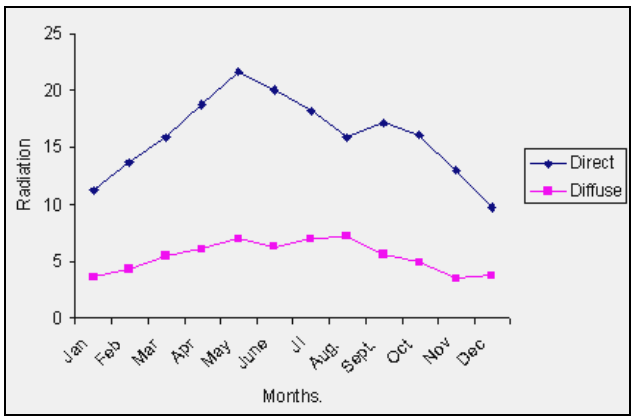

Fig. 3. Shows the pattern of direct and diffuse radiation at Jacobabad, Sindh, Pakistan

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