Pakistan J.Sci.Ind.Res., Vol.27, No.1, February 1984

A STUDY OF AVAILABILITY AND SEASONAL VARIATION OF DIFFUSE SOLAR RADIATION ON HORIZONTAL AND INCLINED SURFACE AT KARACHI, PAKISTAN

Firoz Ahmad and S.A. Hussain

Department of Physics, University of Karachi, Karachi-32, Pakistan

(Received February 19, 1983; revised November 13, 1983)

A detailed study of diffuse solar radiation for Karachi is made. Estimated values of diffuse radiation are obtained by employing different relationship as given by Liu *and* Jordan, Page and Iqbal. From the standard method diffuse solar radiation on various inclined surface are also estimated. The result obtained from these relationships are in good agreement. It has been found that the diffuse solar radiation attains a maxima during the months of May and June.

INTRODUCTION

To design a solar system and predict its performance and efficiency, a knowledge of solar radiation pattern of the area under study is a pre-requisite. If the global solar radiation incident on a place is known, the magnitude of diffuse solar radiation can be estimated. So one has to depend on the parameters such as sunshine hrs per day, daylength, humidity (percent), temperature, number of rainy days etc. to estimate the global solar radiation incident on a particular location. Employing these parameters, estimates of the global solar radiation falling on a horizontal and inclined surface has been made [1&2]. Furthermore the characteristic distribution of global, direct and diffuse solar radiation has also been analysed [3]. These studies provide a guideline to the workers engaged in solar energy research at Karachi.

GLOBAL AND DIFFUSE SOLAR RADIATION; H and H_d

The global solar radiation which is received at the earth's surface is usually composed of two main components namely; direct and diffuse (scattered plus reflected) radiation. The direct radiation comes from the sun in the absence of clouds whereas the diffuse component of the global radiation is obtained from scattering in the atmosphere. The diffuse radiation appears throughout the day with cloudy as well as with clear sky. The value fluctuates from unity (densely overcast) to 0.1 (extremely clear sky). The present study is made in order to investigate thoroughly, the availability and seasonal variation of the diffuse solar radiation from the recently developed relationships of Page [4], Liu and Jordan [5] and Iqbal [6] given for the estimation of the diffuse solar radiation.

ESTIMATION OF DIFFUSE SOLAR RADIATION: H_d

Page [4] developed a correlation between daily global radiation and its diffuse component for location between 40°N and 40°S and suggested the use of the following relationship.

$$\frac{\bar{H}_d}{\bar{H}} = 1.0 - 1.13\ \bar{K}_T, \quad \ldots\ldots\ldots\ldots (1)$$

Where $\bar{K}_T = \frac{\bar{H}}{H_o}$ is the clearness index, H_d the diffuse radiation, and $\bar{H}$ and H_o being the global and extraterrestrial solar radiation respectively. The theoretical correlation between $\bar{H}_d/H$ and $\bar{K}_T$ for the estimation of diffuse solar radiation has been given by Liu and Jordan [5]. These theoretical correlations were mathematically expressed by Klien [7] as

$$\frac{\bar{H}_d}{\bar{H}} = 1.39 - 4.027\ \bar{K}_T + 5.531\ \bar{K}_T^2 - 3.108\ \bar{K}_T^3, \quad \ldots (2)$$

Where $\bar{H}_d$, $\bar{H}$ and $\bar{K}_T$ have their usual meaning as stated in equation [1]. M. Iqbal [6] in his relationship, employed parameters such as H_o, $\bar{H}$ and $\bar{K}_T$ for the estimation of diffuse solar radiation and recommends the use of the following equation,

$$\frac{\bar{H}_d}{\bar{H}} = 0.958 - 0.982\ \bar{K}_T, \quad \ldots\ldots\ldots\ldots (3)$$

The $\bar{K}_T$ values for Karachi in all the three relationships

as developed by Page, Liu and Jordan and Iqbal has been taken from the work of F. Ahmad *et.al* [3]. The diffuse solar radiations are obtained for Karachi using equation (1), (2) and (3). Monthly variation of the daily diffuse solar radiations are shown in Fig.1. alongwith the average value from the three relationships. From the Fig. it can be seen that there is an agreement between the estimated values obtained through Page [4] and Iqbal [6] equations throughout the year while the results obtained from Liu and Jordan [5] are lower in comparison to the other two. For the winter months January to March and October to December Liu and Jordan [5] and Page [4] produce almost identical results. However, in general, there is a good agreement between the values obtained from relationships developed by Page and Iqbal. The low values obtained in case of Liu and Jordan could be due to the shade ring correction which they did not take into account. On the average from the estimated results obtained for Karachi, equation (3) yields the maximum whereas equation (2) gives the lowest values of the diffuse solar radiation throughout the year..

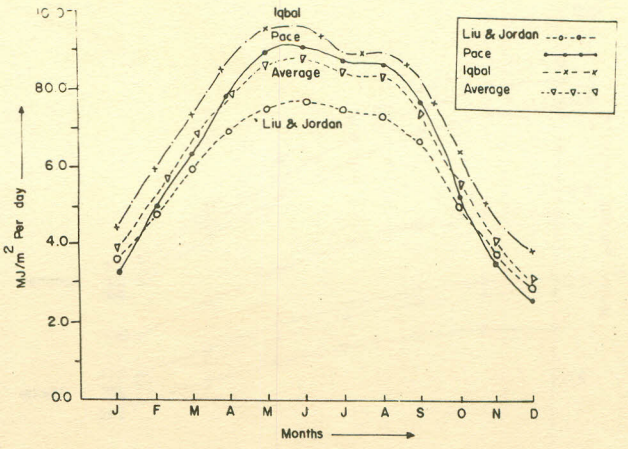

Figure No.1 Variation of diffuse solar radiations on horizontal surface at Karachi, Pakistan, Latitude 24°.54'N

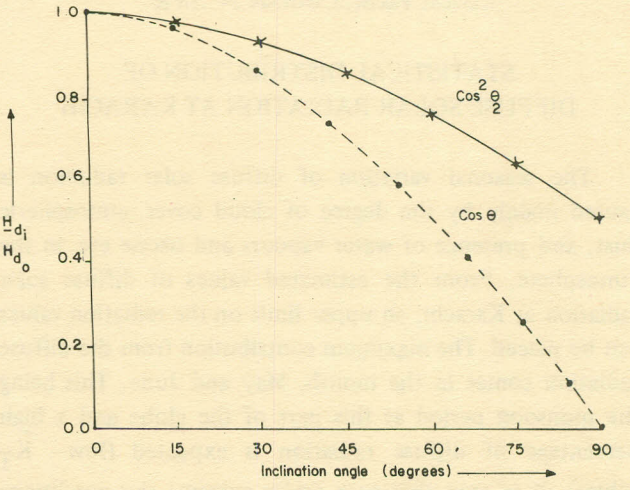

Figure No.2. Diffuse solar radiations for various inclined surface at Karachi, Pakistan. latitude 24°.54'N

DIFFUSE SOLAR RADIATION ON INCLINED SURFACE; H_{d_i}

The knowledge of horizontal global radiation is required in order to predict the efficiency and performance of a solar collector. A solar collector can absorb solar radiation for various orientation with respect to the horizontal position. The titled surface of the solar collector "sees" scattered and reflected radiations from atmosphere and ground, besides direct radiation which comes directly from the solar disk. Estimation of the diffuse solar radiation falling on inclined surface is made for the first time for Karachi, assuming the isotropic distribution of diffuse radiation over the whole of the visible sky hemisphere. The relation employed is derived from Liu and Jordan [8] and is of the following form.

$$\frac{H_{d_i}}{H_{d_o}} = \frac{1 + \cos\theta}{2} = \cos^2\frac{\theta}{2}, \quad \ldots\ldots (4)$$

Where H_{d_i} is the diffuse solar radiation on inclined surface and H_{d_o}, the diffuse solar radiation on a horizontal surface, θ is the tilt or inclination angle.

The ratio of the diffuse solar radiation on inclined surface to that on a horizontal surface; H_{d_i} / H_{d_o} is plotted in Fig.2 to show the effect of increase of inclination angle. The maximum variation from the horizontal value H_{d_o} is calculated for vertical orientation (or $\theta = 90^o$) for which the diffuse radiation values are almost 50% less than what is obtained for horizontal surface ($\theta = 0^o$).

The tilt or inclination angle selected for estimation of diffuse radiation are 15^o, 30^o, 45^o, 60^o, 75^o and 90^o. In Fig.3, the variation of diffuse solar radiation has been shown for summer (APR, MAY, JUN & JUL) and winter months (OCT, NOV, DEC &JAN). From the Fig. it is quite evident that the magnitude of diffuse solar radiation in summer is higher as compared to winter months, though the trend of variation with the increasing angle is almost similar.

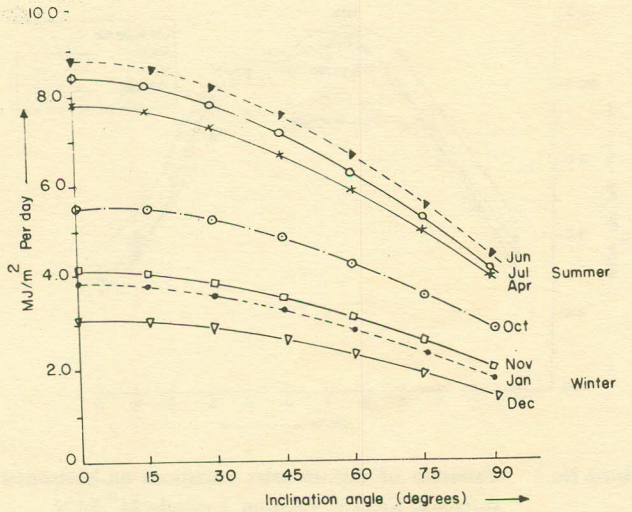

Figure No.3. The effect of tilt on diffuse solar radiations at Karachi, Pakistan. latitude 24°.54'N

STATISTICAL DISTRIBUTION OF DIFFUSE SOLAR RADIATION AT KARACHI

The seasonal variation of diffuse solar radiation is caused mainly by the degree of cloud cover, atmospheric dust, and presence of water vapours and ozone etc. in the atmosphere. From the estimated values of diffuse solar radiation at Karachi, an upper limit on the radiation values can be placed. The maximum contribution from the diffuse radiation comes in the month, May and June. This being the monsoon period at this part of the globe and a high percentage of diffuse radiation is expected (low– $\bar{K}_T$ values). It is seen that even under extreme sky conditions ($\bar{K}_T \leq 0.36$) the diffuse to global ratio does not exceed 0.50 ($\bar{H}_d/\bar{H}$), for Karachi (3), whereas for high $\bar{K}_T$ values (above 0.70) the contribution of diffuse solar radiation to global radiation ($\bar{H}_d/\bar{H}$) is not more than 20 per cent (Ibid).

The sky condition for a particular location is predicted on the basis of percentage of direct and diffuse radiation contributing to the global. The season-wise breakup of the average value of diffuse radiation gives us an idea about the sky conditions at Karachi.

Months	Diffuse radiation	(MJ/m^2 per day)
Nov, Dec and Jan.	Between 2.1 and 4.2	(clear sky)
Feb and Oct.	Between 4.2 and 6.3	
Mar,Apr,Jul,Aug,Sept.	Between 6.3 and 8.4	
May and Jun	Above 8.4	(overcast)

From this breakup, we conclude that sky at Karachi is very clear during the winter months (Oct- to -Dec,Jan & Feb), with the diffuse radiation H_d lying in the range of 2.1 and 4.2MJ/m^2 per day. The sky conditions are fairly clear for the summer months (Mar,Apr, Jul-to-Sept.) and a poor sky condition is exhibited in the monsoon months May and June, during which contribution of diffuse to global radiation attains a maxima and transmission through clouds goes to minimum (low $\bar{K}_T$ –values).

The present studies regarding the availability and seasonal variation of diffuse solar radiation at Karachi for horizontal and inclined surface will serve as ready reference as far as diffuse radiation approximations are concerned.

REFERENCES

1. Firoz Ahmad, S.A. Husain, S.M.M.R. Naqvi and M. Wasim Akhtar, Pakistan J.Sci.Ind.Res., 24, 95, (1981).
2. Firoz Ahmad, S.A. Husain and S.M.M.R. Naqvi, Renewable Energy Review Journal, RERIC/AIT, Bangkok, Thailand, 4, 10-19 (1982).
3. Firoz Ahmad, S.A. Husain, S.M.M.R. Naqvi and M. Wasim Akhtar, Pakistan J. Sci.Ind.Res., 24, 171 (1981).
4. J.K. Page, Proc. of UN Conf. on New sources of Energy, Rome, 1961. Conf. Paper No.35/5/98.
5. Y.H.Liu and R.C. Jordan, and characteristic distribution of Direct, Solar Energy, **4**, 1-19 (1960).
6. M. Iqbal, Solar Energy, **22**, 81-86 (1979).
7. S.A. Klien, Solar Energy, **19**, 325-329 (1977).
8. Y.H. Liu and R.C. Jordan, Solar Energy, **7**, 53 (1963).