Estimation of Diffuse Solar Radiation from Clearness Index for Multan, Southern Punjab, Pakistan

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Abstract: Empirical correlations have been developed for Multan for the estimation of Diffuse Solar Radiation (DSR) as a function of clearness index (K_T). The diffuse solar radiation are also estimated by the relationship as given by Liu and Jorden, Page and Iqbal. All these correlation shows a peak value of diffuse solar radiation for the months of July & August (monsoon months). The diffuse to global (total) radiation ratio is 0.317. The presently developed correlation are fine agreement with the result obtained by earlier models. It is inferred from the result that solar energy has bright prospects as far as its application and utilization is concerned.

Keywords: Diffuse Solar Radiation, Global Solar Radiation, Clearness Index, Multan, Correlation.

1. INTRODUCTION

In the era of energy crisis throughout the World the research workers are engaged in exploring the possibilities of utilization of renewable energy sources to overcome the present energy crisis. This energy deficit is the result of industrialization, urbanization, changing life style and increase in growth rate of energy utilization. The alternate energy resources Solar, Wind and Biomass has bright prospects for the future. Solar energy is inexhaustible, clean and abundant source of energy. Solar radiation incident on horizontal surface is composed of Beam (Direct) and diffuse radiation. The direct solar radiation comes directly from the Sun and diffuse radiation are those which are scattered in the atmosphere, absorbed and reflected. The amount of diffuse solar radiation in the atmosphere depends upon the amount of water vapour contents, degree of turbidity and cloud cover. The value of diffuse solar radiation fluctuates throughout the year due to change in the atmospheric conditions.

The knowledge of diffuse radiation is required in order to study the performance of solar thermal devices. The global solar radiation is measured in all the major locations of the world but diffuse solar radiation are recorded at few places. In Pakistan Six stations record global solar radiation but diffuse solar radiation is not measured at all due to lack of facilities and cost. Under these conditions empirical correlations are developed to estimate the diffuse component of the total solar radiation. In this paper the diffuse solar

radiation as a function of clearness index $K_T = H/H_o$ is estimated for the first time for Multan. Here H is the global solar radiation and H_o is the extraterrestrial solar radiation. Multan is a major city of southern Punjab located at 30° 12′ N latitude. It receives abundant sunshine throughout the year [14].

2. MATHEMATICAL FORMULATION

The data for Multan has been obtained from Pakistan Metrological Department (PMD) it is an average for 14 year that is monthly average from 1980 to 1994. The estimation of Diffuse Solar Radiation (DSR) **H_d** has been made by many authors [1-13]. The contribution of diffuse solar radiation to the total solar radiation is expressed as a function of clearness index $K_d = H_d/H = f(K_T)$.

Liu and Jorden [1] correlation, later developed by Klien [2] is of the form,

$$K_d = H_d/H = 1.39 - 4.027(K_T) + 5.531(K_T)^2 - 3.108(K_T)^3 \tag{1}$$

While Page [3] correlation is expressed as,

$$K_d = H_d/H = 1.00 - 1.13(K_T) \tag{2}$$

And Iqbal [4] in his correlation employing the parameter is given as,

$$K_d = H_d/H = 0.958 - 0.952(K_T) \tag{3}$$

Beside this regression equation of Ist and 2nd order are also expressed for Multan for a better estimation

$$K_d = H_d/H = a_1 + a_2(K_T) \tag{4}$$

And

Table 1:   Input Parameters for Diffuse Solar Radiation: Multan Station (Latitude: 30° 12' N)

Months	H_o (MJ/m^2 d)	H (MJ/m^2 d)	$K_T = H/H_o$
Jan	20.894	12.678	0.6068
Feb	25.556	15.408	0.6029
Mar	31.126	18.758	0.6026
Apr	36.335	22.735	0.6257
May	39.530	24.201	0.6122
Jun	40.654	23.531	0.5788
Jul	39.988	23.196	0.5801
Aug	37.456	21.731	0.5802
Sep	32.928	20.391	0.6193
Oct	27.127	16.748	0.6174
Nov	21.951	13.859	0.6314
Dec	19.544	11.556	0.5913

(Source: C.D.P.C Pakistan Metrological Dep. Karachi).

$$K_d = H_d/H = a_3 + a_4 (K_T) + a_5 (K_T)^2 \tag{5}$$

For the purpose of development of the correlation the value of H the global solar radiation and extraterrestrial solar radiation H_o, had been taken from Table **1**. Minitab 17 has been used for all the mathematical work.

3. RESULT & DISCUSSION

All the correlation due to Liu and Jorden, Page, Iqbal and the presently developed equations (4 and 5) are employed for the estimation of DSR at Multan.

The equation developed for Multan are presented for the estimation of DSR, given below as

$$K_d = H_d/H = 0.8715 - 0.939 (K_T) \tag{6}$$

And

$$K_d = H_d/H = 0.8515 - 0.8743 (K_T) - 0.0552 (K_T)^2 \tag{7}$$

The estimated values of DSR obtained by the correlation (Eq.1-3, 6 &7) are given in Table **2** and are shown in Figure **1**. It is observed from it that all the curves obtained through these correlations exhibits the identical trend of variation, showing a maxima in the

Table 2:   Diffuse Solar Radiation of Multan (At Horizontal Surface)

| Months	Liu & Jorden Eq.1 (MJ/m^2 d)	Page Eq.2 (MJ/m^2 d)	Iqbal Eq.3 (MJ/m^2 d)	Present work Eq.6 (Linear) (MJ/m^2 d)	Present work Eq.7 (Quadratic) (MJ/m^2 d)
Jan	3.650	3.985	4.591	3.825	3.819
Feb	4.481	4.911	5.638	4.705	4.697
Mar	5.459	5.984	6.869	5.733	5.723
Apr	6.223	6.660	7.811	6.456	6.443
May	6.869	7.459	8.635	7.179	7.166
Jun	7.269	8.140	9.168	7.718	7.706
Jul	7.143	7.991	9.009	7.581	7.569
Aug	6.690	7.484	8.437	7.100	7.089
Sep	5.680	6.122	7.135	5.914	5.903
Oct	4.689	5.064	5.891	4.887	4.878
Nov	3.735	3.971	4.684	3.862	3.854
Dec	3.461	3.835	4.361	3.655	3.649
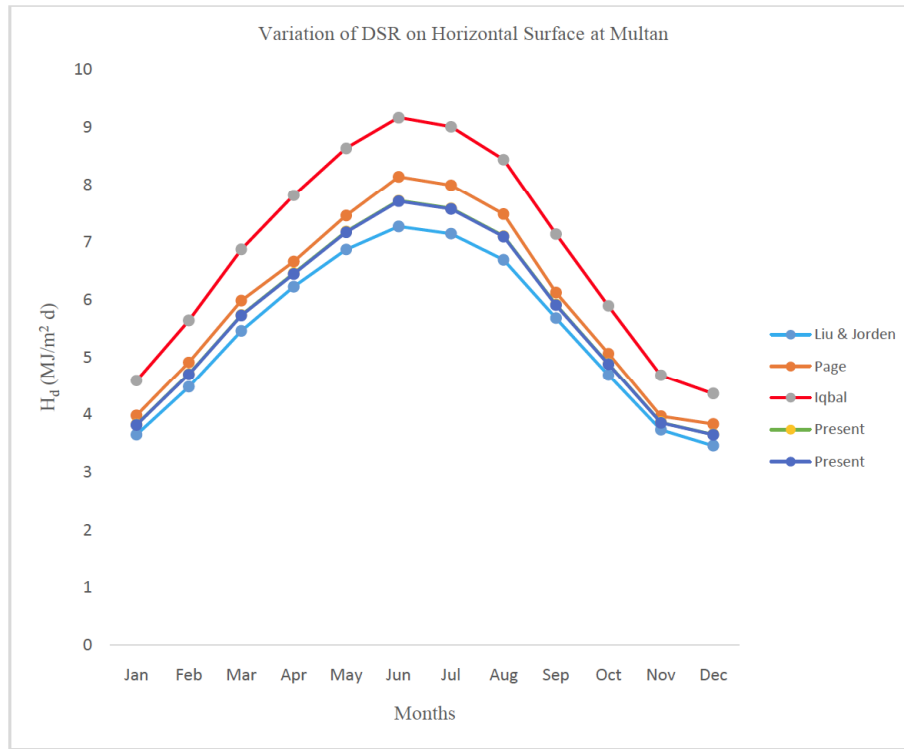
Figure 1: Annual Variation of DSR at Multan. (On Horizontal Surface, Latitude 30° 12' N).

monsoon months (Jun-Aug). It is also observed that the estimation of diffuse solar radiation by Liu and Jorden equations are lower and that obtained by Iqbal equation are higher. However the values obtained by Page equation and the presently developed equation corresponds with each other.

The annual average of H_d/H obtained from the five correlations is 0.320, showing an agreement with Page

equation which is 0.317. Table **3** gives the value of H_d/H obtained from five correlations from this it is observed that throughout the year the presence of diffuse solar radiation to the total radiation is not more than 30 percent.

The diffuse solar radiation H_d has a minima 3.65 MJ/m^2 d in December and 7.71 MJ/m^2 d is the maxima observed in June. This is the period when diffuse solar

Table 3: Ratio of Diffuse to Global Solar Radiation for Multan

Months	H_d/H	H_d/H	H_d/H	H_d/H	H_d/H
	LJ	Page	Iqbal	Present work (Eq.6)	Present work (Eq.7)
Jan	0.288	0.314	0.380	0.302	0.301
Feb	0.291	0.319	0.384	0.305	0.305
Mar	0.291	0.319	0.384	0.306	0.305
Apr	0.274	0.293	0.362	0.284	0.283
May	0.284	0.308	0.375	0.297	0.296
Jun	0.309	0.346	0.407	0.328	0.327
Jul	0.308	0.345	0.406	0.327	0.326
Aug	0.308	0.344	0.406	0.327	0.326
Sep	0.279	0.300	0.368	0.290	0.289
Oct	0.280	0.302	0.370	0.292	0.291
Nov	0.270	0.287	0.357	0.279	0.278
Dec	0.300	0.332	0.395	0.316	0.316
AVG	0.290	0.317	0.383	0.304	0.304

radiation is high due to monsoon period (overcast sky). The low value of K_T shown in Table **1** supports the results.

The estimated value of diffuse solar radiation from the five correlation shows the same trend. The Page correlation and the linear and quadratic equation developed for Multan are recommended for predicting the diffuse solar radiation since there is a fine agreement between these correlations throughout the year.

The low value of H_d/H for Multan supports the application and utilization of solar energy. The sky conditions are clear with less atmospheric pollution, with the exception of monsoon period.

This study has been done for the first time for Multan and hence will provide a strong database as far as solar energy utilization in this part of the country is concerned.

4. ACKNOWLEDGEMENT

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