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 cleanness index \( K_T = \frac{H}{H_o} \) 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,

\[
K_d = \frac{H_d}{H} = 1.39 - 4.027(K_T) + 5.531(K_T)^2 - 3.108(K_T)^3
\]

While Page [3] correlation is expressed as,

\[
K_d = \frac{H_d}{H} = 1.00 - 1.13(K_T)
\]

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

\[
K_d = \frac{H_d}{H} = 0.958 - 0.952(K_T)
\]

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

\[
K_d = \frac{H_d}{H} = a_1 + a_2 (K_T)
\]

And
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

\[
K_d = \frac{H_d}{H_o} = a_3 + a_4 (K_T) + a_5 (K_T)^2
\]  

(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.

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

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


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)

<table>
<thead>
<tr>
<th>Months</th>
<th>Liu &amp; Jorden</th>
<th>Page</th>
<th>Iqbal</th>
<th>Present work</th>
<th>Present work</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eq.1 (MJ/m(^2) d)</td>
<td>Eq.2 (MJ/m(^2) d)</td>
<td>Eq.3 (MJ/m(^2) d)</td>
<td>Eq.6 (Linear) (MJ/m(^2) d)</td>
<td>Eq.7 (Quadratic) (MJ/m(^2) d)</td>
</tr>
<tr>
<td>Jan</td>
<td>3.650</td>
<td>3.985</td>
<td>4.591</td>
<td>3.825</td>
<td>3.819</td>
</tr>
<tr>
<td>Feb</td>
<td>4.481</td>
<td>4.911</td>
<td>5.638</td>
<td>4.705</td>
<td>4.697</td>
</tr>
<tr>
<td>Mar</td>
<td>5.459</td>
<td>5.984</td>
<td>6.869</td>
<td>5.733</td>
<td>5.723</td>
</tr>
<tr>
<td>May</td>
<td>6.869</td>
<td>7.459</td>
<td>8.635</td>
<td>7.179</td>
<td>7.166</td>
</tr>
<tr>
<td>Jun</td>
<td>7.269</td>
<td>8.140</td>
<td>9.168</td>
<td>7.718</td>
<td>7.706</td>
</tr>
<tr>
<td>Aug</td>
<td>6.690</td>
<td>7.484</td>
<td>8.437</td>
<td>7.100</td>
<td>7.089</td>
</tr>
<tr>
<td>Sep</td>
<td>5.680</td>
<td>6.122</td>
<td>7.135</td>
<td>5.914</td>
<td>5.903</td>
</tr>
<tr>
<td>Oct</td>
<td>4.689</td>
<td>5.064</td>
<td>5.891</td>
<td>4.887</td>
<td>4.878</td>
</tr>
<tr>
<td>Nov</td>
<td>3.735</td>
<td>3.971</td>
<td>4.684</td>
<td>3.862</td>
<td>3.854</td>
</tr>
<tr>
<td>Dec</td>
<td>3.461</td>
<td>3.835</td>
<td>4.361</td>
<td>3.655</td>
<td>3.649</td>
</tr>
</tbody>
</table>
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

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|}
\hline
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) \\
\hline
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 \\
\hline
\end{tabular}
\caption{Ratio of Diffuse to Global Solar Radiation for Multan}
\end{table}
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 $H_0/H$ 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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REFERENCES


[14] Computerized Data Processing Center. Pakistan Meteorological Department, University Road Karachi, Pakistan. (Data providing Ref. No. CDP-7(4)/3/2012).