ESTIMATION OF GLOBAL AND DIFFUSE SOLAR RADIATION FOR MULTAN, PUNJAB, PAKISTAN

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Abstract — In this paper the Global and Diffuse solar radiation on horizontal surface over Multan city have been studied using sunshine hour data of the area to perceive the feasibility of solar panel utilization in Multan area. Multan is situated at latitude 30°12´ and longitude 71°28´.In Multan temperature ranges between 10°C in winter to 47°C in summer. The results obtained shows that contribution of diffuse solar radiations is high in February. The appearance of clouds is also high in February as compared to other months. The global solar radiation is high during March to October which indicates that the solar potential is high in these months. Due to high temperature in summer one can extract thermal energy also. The sky condition is clear during summer so K_t value (cloudness index) is low remains between 62-67%.The estimated values indicate that this part of Punjab has higher solar potential and solar panels can be used for power generation. The solar energy can be utilized throughout the year in this part of Punjab, Pakistan.

Keywords: Global and Diffused solar radiation, solar potential, province of Punjab, solar radiation power generation.

I. INTRODUCTION

Pakistan is situated in solar energy belt where abundance of sun shine is available throughout the year as witnessed from annual average mean daily solar radiation depicted in Figure.1.

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The most plentiful power source we have in Pakistan is solar. Punjab is the north eastern province of Pakistan and Multan is the one of the important city from the perspective of population and historical background.

Punjab province is technically suitable to exploit renewable energy resources because it has abundant Sun shine. Punjab is a moderate insulation Province. It receives 5.4 to 5.8 KWH annual average daily solar radiations as shown in Figure.2.

It receives about 1KW of solar energy per square meter for 8 to10 hours on the average per day. The number of sunshine hours amounts to 3000 to 4000 per year.

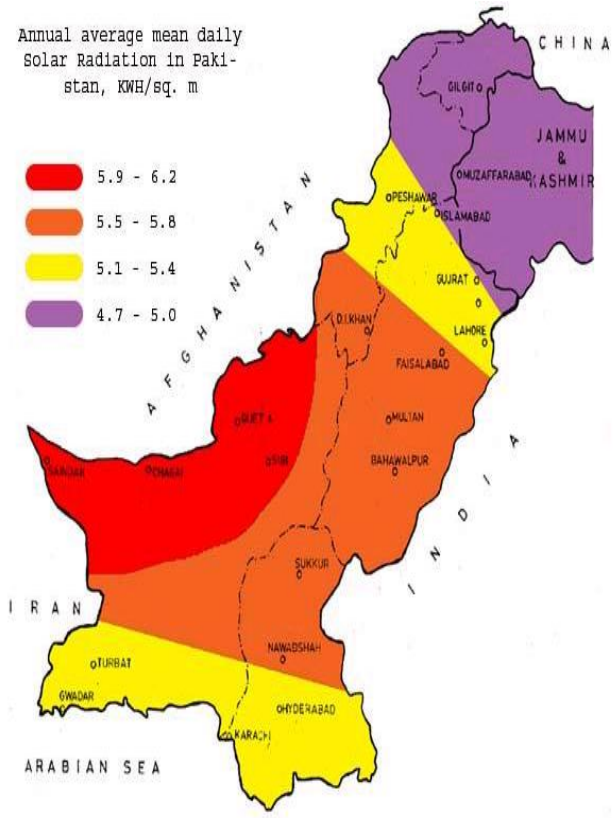

Figure. 1: Annual average means daily solar radiation

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Figure.2: Map of Punjab Province in Pakistan [1]

In many Punjab villages wood and animal dung is used as a cooking fuel. This causes wide spread deforestation and women are also forced to walk many miles each day to gather wood. Moreover their health badly suffers from the smoke emitted, carbon dioxide/monoxide gases from cooking on wood fire. The other aspect is that about 60% of population lives in more than 40000 villages that are very far away from national grid. One of the challenges is provision of electricity to deprived areas is to connect these villages to the national grid which would need planning at national/provincial level having worked out technical feasibility and cost viable. An alternate solution is to utilize solar potential thus giving each house a solar based system which would be autonomous and cost efficient. This would empower people economically and socially.

Moreover there is a shortfall of power in the province of Punjab. Due to this deficit of electricity the province is constrained to exercise load shading. In the province there is 06 hours load shading in cities and 08-10 hours load shading in villages. This shortfall of power is effecting the business growth, industries production and to common people efficiency and in life style. Renewable resources produce green energy free of pollution can compensate for this shortfall.

Solar radiation data [1][2] is essential as a fundamental input for solar energy application such as photovoltaic and solar thermal system implementation. A detail analysis on availability of solar radiation on horizontal surface is vital for the optimum design and study of solar potential. A number of empirical formulas have been developed to estimate the global and diffuse solar radiation using sunshine hour data [3][4]. The methodology used to determine the global solar radiation (H) as suggested by Sangeeta and Tiwari [5][6]. In this technique the first order regression coefficient of Angstrom type correlation were used to investigate the Global solar radiation. The diffuse solar radiation has been calculated using Page, Liu and Jorden method [7][8]. The K_T (Cloudiness index) values are also calculated [9][10].

Table.1: Geographical location of Multan, Punjab, Pakistan

City	Latitude N		Longitude E		Maximum& Minimum Temperature °C		Duration Sunshine Hour
	deg	min	deg	min	Summer	Winter	
Multan	30	11	71	28	48 6	37 2	5 years

II.METHOD OF PREDICTION

The Angstrom equation relates monthly-average daily irradiation to clear day irradiation and the number of hour's (n) of bright sunshine [11].

$$H/H_0 = a + b(n/N) \quad (1)$$

Where H is the Global solar radiation

H_0 is the Extraterrestrial radiation

'a' and 'b' are the climatological regression coefficients

'n' is the monthly mean daily number of sunshine hour

N is the day length of the location

Regression coefficients 'a' and 'b' have been obtained from the relationship given by [6]:

$$a = -0.110 + 0.235\ cos\Phi + 0.323\ (n/N) \quad (2a)(2b)$$

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

Where Φ the declination angle and (n/N) isthe percentage of possible sunshine hour

The mean monthly global solar radiation, H for Karachi, Hyderabad, Nawabshah, Chore and Ptidan were calculated from expression (1). We indicate that in literature there are other methods to estimate these constants are also available such as

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Rietveld [11][12], Glover and McCulloch [13] and Gopina than[14][15].

a. *Extra-Terrestrial Radiation on Horizontal Surface (H_0)*

The solar radiation outside the atmosphere incident on the horizontal surface is given by the following expression [16][17]

$$Ho= (24*3600)/\pi\ Isc[(1+0.033Cos(360n/365)]$$

$$[Cos\phi Cos\delta SinWs + 2\pi\ Ws/360\ Sin\phi Sin\delta] \quad (3)$$

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

$$\delta = 23.45\ sin\{360\ x\ 248 + n/365\} \quad (4)$$

$$cosWs = -tan\theta tan\delta \quad (5)$$

b. Prediction of Diffuse Solar Radiation (H_d)

The diffuse solar radiation H_d can be estimated by an empirical formula that correlates the diffuse solar radiation component H_d to daily total radiation H. The widely used correlation equation, developed by Page [7] and Liu and Jordan [8] respectively is

$H_d/H = 1.00 - 1.13K_T$ (6)

$H_d/H = 1.390 - 4.027K_T + 5.53(K_T)^2 - 3.108(K_T)^3$ (7)

Where H_d is monthly mean of daily Diffuse solar radiation and H is the daily Global solar radiation and K_T is the clearness index [19][18][14].

$$K_T = H/H_0 \quad (8)$$

III.RESULTS AND DISCUSSION

The monthly mean sunshine hour and day length for Multan is shown in Table-3.From this it appears that the sunshine duration is 07 to 09 hours and the day length 10 to 14 hours in winter and summer for Multan city as shown in Figure-3.The Angstrom coefficient 'a' and 'b' are evaluated using relationship given by Sangeeta and Tiwari. The monthly average daily Global solar radiation H, the extraterrestrial solar radiation H_0 and the diffuse solar radiation H_d for Multan was evaluated and shown in Figure-4below.

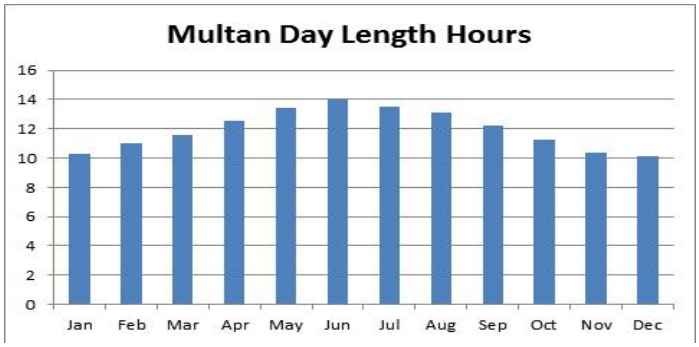

Figure.3: Multan Daily Annual Sunshine Hours

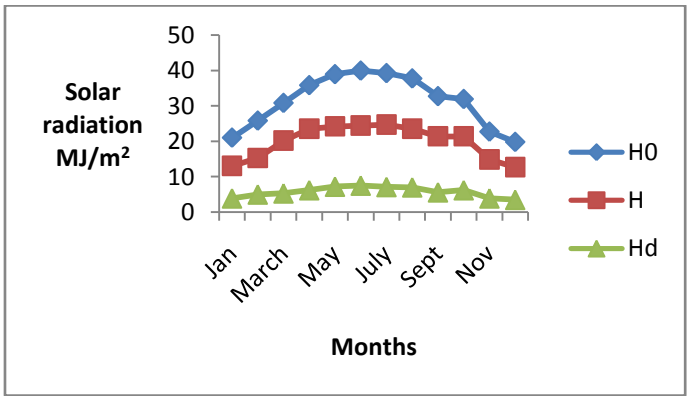

Figure.4: Monthly variation of Extra-terrestrial, Global and Diffuse solar radiation for Multan.

The Global solar radiation remains higher from March to October and low during November to February (Table-4).The availability of direct radiation is therefore very encouraging from the utilization point of view. The transmission of H_d/H_o is only 17% which rises to 19% in January to February(Table-4). From the observation of clearness index and ratio of diffuse to global we concluded that the presence of clouds is almostlow throughout the year with the exception of February in which clouds appearance is a bit high, so whole year is favorable for solar energy utilization.

a. Statistical Distribution of Global Solar Radiation

Shown in Table-2 the statistical distribution of global solar radiation of Multan city which indicates that the availability of global solar radiation at Multan is 71 to 74%during summer and winter months while it is only 68% in the month of February. It is higher even in the monsoon months July and August.

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Table.2: Statistical Data of Global Solar Radiation

Jan-April	68 to71%
May -June	70 to 71%
July-Augu	71to 72%
Sept-Dec	73 to 76%

b. Sky Condition at Multan

The transparency of atmosphere is indicated by the fraction of extraterrestrial radiation that reaches the earth surface as global solar radiation. It is a measure of the degree of clearness of the sky. Clearness index is given as;

$K_t = H/H_0$

It is the ratio of Global solar radiation to extraterrestrial insulation. From the calculated value it is encouraging to note that the sky remains very clear almost throughout the year except the month of February when cloud appears. The K_t value (Clearness Index) remains 0.65 to 0.67 during March to October. In monsoon months July and August the sky remains clear as shown in Figure-5.

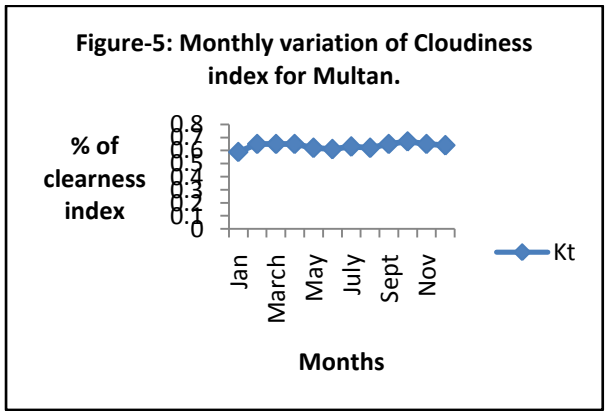
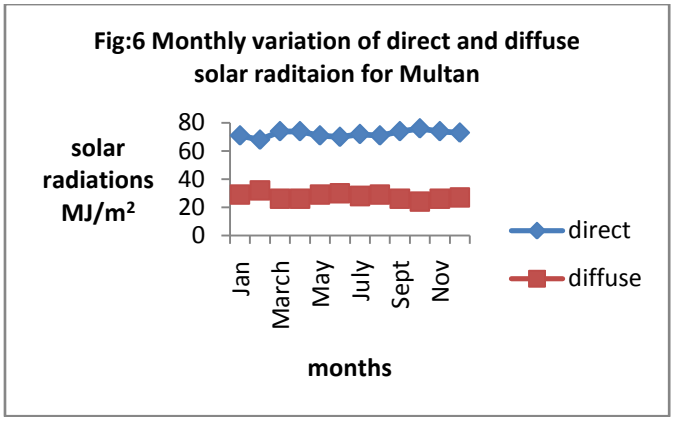


Figure. 5: Monthly variation of Cloudiness index for Multan.

c. Direct and Diffused Solar Radiation

From Figure-6, it appears that the contribution of diffuse solar radiation is higher during May to August (29% to 30%) where as the direct solar radiation is higher during March-April and September to November i.e. 74%.



The diffuse solar radiation for Multan is estimated by Page and Liu and Jordan as no station in Pakistan measures diffuse solar radiation .From the estimated result it is seen that contribution of diffuse solar radiation is almost same and high during monsoon months, whereas low throughout the year.The Liu and Jordan method predicts lower values than Page correlation.

IV. CONCLUSION

The studied work reported in this paper indicates that the solar energy utilization has an intense prospect in Multan, Punjab, Pakistan. The estimated value of global and diffuse solar radiation reveals that solar radiation can be effectively utilized to compensate the energy deficit. Since limited research work on such topic for Multan city has been reported prior to this work, so this paper is expected to be helpful to determine the solar potential of Multan area for experts of energy. In Multan the summer is very hot and shiny almost throughout the year so solar energy can be utilized very efficiently.

Table.3: Input parameters for estimation of monthly average Global Solar Radiation for Multan

Months	Monthly mean sunshine hour n	Monthly mean day length N	Possible sunshine hour n/N
Jan	6.5	10.3	0.63
Feb	6.3	10.9	0.57
March	8.5	11.8	0.72
April	9.1	12.7	0.72
May	8.5	13.5	0.63
June	8.4	13.8	0.60

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July	8.9	13.7	0.65
August	8.4	13.0	0.65
September	8.9	12.1	0.73
Oct	8.9	11.2	0.79
Nov	7.4	10.4	0.75
Dec	7.0	10.0	0.70

Table.4: Solar Radiation data for Multan, Punjab, Pakistan

Months	H_0 MJm^2d	H MJm^2d	H_d MJm^2d	K_T	H_d/H_0
Jan	21.0	13.1	3.9	0.62	0.18
Feb	25.8	15.3	5.0	0.59	0.19
March	30.8	14.2	5.3	0.65	0.17
April	35.8	23.5	6.2	0.65	0.17
May	38.9	24.2	7.2	0.62	0.18
June	39.99	24.4	7.5	0.61	0.18
July	39.2	24.7	7.1	0.63	0.18
August	37.7	23.5	7.0	0.62	0.18
Sep	32.7	21.4	5.6	0.65	0.17
Oct	31.9	21.4	5.2	0.67	0.16
Nov	22.7	14.9	3.9	0.65	0.17
Dec	19.8	12.7	3.5	0.64	0.17

REFERENCES

[1] Angstrom A Solar and terrestrial radiation, "Quarterly Journal of Royal Meteorological Society" vol.10(10), 2012.

[2] Black J.N, Bonython C.W and Prescett J.A. , "Solar radiation and duration of Sunshine" ,Q.J.R Metro.Soc. vol. 50, 1954, pp.121-6.

[3] Glover,J and McCullochF, "The empirical relationship between solar radiation and hours of Sunshine", Q.J.R.Met.Soc. vol. 84, 1958, pp.359.56-60.

[4] Gopinathan K.K, , "A new model for estimating total solar radiation-Solar and Wind Technology", VOL.5(1), 1988, PP.107-109.

[5] Tiwari G.N and Suleja Sangeeta, "Solar thermal engineering system", Narosa publishing house 1997, New Delhi, India.

[6] Reddy, S.J, "An empirical method for the estimation of net radiation intensity solar Energy", vol.13, 1971, pp.291-292

[7] Liu,Y.H and Jordan R.C., " The inter relationship and characteristic distribution of direct, diffuse and total solar radiation from metrological data, Solar energy", vol. 4, 1960, pp.1-19.

[8] Sabbagh J.A Sayigh A.A.M and El.Salam E.M.A "Estimation of total solar radiation from meteorological data solar energy" , vol.19, 1977, pp.307-311.

[9] AhmedAkhlaque M., Ahmed Firoz and Mwasim Akhtar, "Estimation of Global and Diffuse Solar Radiation for Hyderabad, Sindh, Pakistan", Journal of Basic and Applied Sciences, vol.5(2), 2009, pp. 73-77

[10] Ahmed, Firoz and UlfatIntikhab, "Empirical model for the correlation of Monthly Average Daily Global Solar Radiation with hours of sunshine on a horizontal surface at Karachi, Pakistan", Turkish J. Physics,vol. 28, 2004, 301-307.

[11] Ahmed Firoz and UlfatIntikhab, "Empirical model for the correlation of Month average daily global solar radiation with hours sunshine on a horizontal surface at Karachi Pakistan", Turkish J physics,vol. 28, 2004, 301-307

[12] Ulfat, Intikhab Ahmed Firoz Siddiqui Imran, "Determination of Angstrom coefficient for the prediction of monthly average daily global solar horizontal surface at Karachi Pakistan kar" .unijoursci 2005. 33(1 and 2),pp.7-11

[13] tiwari G.N and Suleja Sangeeta, " Solar thermal engineering system narosa publishing house new dehliindia" ,1997,

[14] NASA,http://eosweb.larc.nasa.gov/sse/,view:8/10/2.12

[15] Pakistan meteorological department, www.pmd.gov.pk/observatories/index.html, visited:10-10-2012

[16] frèreetal graph given in AA flocas paper estimation and prediction of global solar radiation over Greece solar energy 1980.24:63-70

[17] Duffie JA and Beckman WA solar engineering of thermal processes john-Wileyand sons New York.1991.

[18] Abdullah,YAG. And Farugh, GM. , "Contribution to the study of solar radiation in Abu Dhabi. Energy Conv. and Management", vol.28(1), 1998, pp.63-67

[19] Ahmed,Firoz,Hussain,SA.,Naqvi, SMMR. and Akhtar, M Wasim, , "Characteristic Distribution of Total, Direct and Diffuse Solar Radiation, Pka. Jour. Sci and Res", vol.24 (5-6), 1981, pp.171.

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