Variation of Estimated Insolation from East to West in Uttar Pradesh, India

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***Abstract*—Solar Energy at Allahabad east of Uttar Pradesh, India longitude 81.846 (81° 50' east), latitude 25.436 (25° 26' north) and Ghaziabad west of Uttar Pradesh, India longitude 77.417 (77° 25' east), latitude 28.667 (28° 40' north) depends the variation of Global and Diffuse component of solar radiation throughout the year. The analysis based estimation of diffuse solar radiation quantitatively wise is very high during the rainy season (last days of June, July and August) individually in both cities of the state . From the estimated values it is found that, solar energy can be much more utilized very efficiently throughout the year with the exception of rainy season from east to west of the state, Uttar Pradesh, India. In the paper discusses the variation of monthly average of sun shine hour and monthly variation of complete solar radiation are estimated and how much the solar radiation be utilize from east to west of the state Uttar Pradesh.**

***Keywords*— Allahabad; Ghaziabad; India; Solar radiation; Sunshine Hour; Uttar Pradesh.**

I. INTRODUCTION

In future the world will face to energy crises due to shortage of conventional energy resources like as coal, wood, water, nuclear fuel, oils and gases. This is a matter of major concern for the entire countries whose economy heavily depend on its use of energy. Under this circumstances we should go alternative arrangement i.e non conventional energy resources should be utilized with great conversion efficiency to sort out the energy demand. Non-conventional energy resources like solar energy, wind energy, tidal and biomass are the second option to develop the future power and then its complete utilization with high efficiency. The sun's heat and light provide an abundant source of energy that can be harnessed in many methods and different variety of technologies that have been developed to take advantage of solar energy. Presence of solar radiation on flat horizontal surface is a primary requirement for measurement and optimum design and study of solar energy conversion system. Complete data information of Solar radiation is available for most part of the world, but it is not available for some countries due to lack of measuring equipments and techniques involved.

Global solar radiation in India is measured at many work stations namely Chennai, Kolkata, Delhi and Pune [18], abroad Karachi [17] in Pakistan and at Kebbi in Nigeria [19]. It is rather important to develop different methods to estimate the global and diffuse solar radiation using climatologically different parameters involved. Several empirical formulas have been used for this work. These parameters are sunshine hours [1]-[3], relative humidity [4], declination angle and latitude [5], altitude, latitude, some rainy days, sunshine hours and locations, maximum and minimum temperature and precipitate, water, turbidity and surface albedo [6]. There are many other works have developed for the calculation of direct, global and diffuse solar radiation employing various climatologically parameters [7]-[11]. In this paper, solar radiation estimation have been done for the first time for Ghaziabad and Allahabad, Uttar Pradesh to utilize the power developed by solar radiation for useful purpose. This paper will discuss the potential of estimation and utilization the solar energy at Ghaziabad (west) and Allahabad (east) of the state, Uttar Pradesh, India shown in fig.1 and how much the entire solar radiation shows the variation in values to solve the energy deficit in this region throughout the year.

I. WHY RENEWABLE ENERGY

Till today, the country is nowhere near its goal of

Fig.1 Map of Uttar Pradesh, India

Till today, the country is nowhere near its goal of energy with equity. India has a vast population of over 1.21 billion (2011 census) with 70% of the total population living in rural areas. Out of 44.7% of the total rural population compared to 7.3% of urban population do not have access to electricity due to the lack of generation, transmission and distribution by shortage of conventional fuels so renewable energy resources include solar energy, wind energy and biomass. A judicious mix of these options can bring sustainable development of energy demand and pollution free environment in the country and help us to improve quality of life as well as the economy of the country.

II. ESTIMATION BY FORMULAS

Angstrom equation (1) is frequently used for calculating the monthly average daily solar radiation

$$\frac{H_g}{H_o} = a + b\left[\frac{\bar{s}}{\bar{S}}\right] \tag{1}$$

Where H_g is the monthly mean global solar radiation per day on a horizontal surface at a specific location. H_o is the monthly mean radiation per day on a horizontal surface in the absence of atmosphere at that location. s is the observed monthly mean number of sunshine hours per day , S is the monthly mean value of day length. s/S is often called the percentage of possible sunshine hour. Climatologically regression coefficient may be obtained by different models used. The coefficient a and b depends on the seasonal regional parameters. In this paper have been obtained the regression coeffcient from the relationship given as in equation (2) and (3)

$$a = -0.110 + 0.235\cos\phi + 0.323\left(\frac{\bar{s}}{\bar{S}}\right) \tag{2}$$

$$b = 1.449 - 0.553\cos\phi - 0.694\left(\frac{\bar{s}}{\bar{S}}\right) \tag{3}$$

whereas there are many methods to evaluate these Regression coefficient [9].These Constants have been calculated from equation (2) and (3) then these are

a = 0.29
b = 0.53

for Ghaziabad west part of the state Uttar Pradesh.

a = 0.30
b = 0.51

for Allahabad east part of the state Uttar Pradesh.

H_o may be calculated by illustrated equation (4) of Duffi and Beckman [12]. for both cities of the state Uttar Pradesh, India

$$H_0 = \frac{24\times 3600}{\pi}G_{SC}\left[1 + 0.033\cos\left(\frac{360n}{365}\right)\right]\times$$

$$\left(\sin\omega_S\cos\delta\cos\phi + \left(\frac{\pi\omega_S}{180}\right)\sin\phi\sin\delta\right) \tag{4}$$

Where G_{sc} is the solar constant, ϕ is the latitude, δ is the solar declination, ω_S is the sunset hour angles and n is nth day of the month where

$$\delta = 23.45\sin\left[\frac{360(284+n)}{365}\right] \tag{5}$$

$$\cos\omega_S = -\tan\phi\tan\delta \tag{6}$$

The diffuse solar radiation H_d can be estimated by an empirical formula illustrated equation (7) which correlates the diffuse solar radiation component H_d to the daily total radiation H_o. The correlation equation is frequently used which is developed by Krieth.

$$\frac{H_d}{H_g} = 1.411 - 1.696\left(\frac{H_g}{H_o}\right) \tag{7}$$

III. RESULT AND ANALYSIS

The entire input parameter for calculating monthly average daily solar radiation H_o in the absence of atmosphere and also calculating of monthly average daily global solar radiation H_g at Ghaziabad west of the state and Allahabad east of Uttar Pradesh, India is given in Table 1 and Table 2. With reference of these tables it is observed that sunshine duration is about 63&65 percent throughout the year. The regression coefficient "a" and "b" parameters were taken by calculation from the relationship illustrated equations (2) and (3) as a = 0.29 and b = 0.53 for Ghaziabad and a=0.30 and b=0.51 for Allahabad. the monthly average daily global solar radiation H_g is estimated using equation (1). The comparison of percentage possible sunshine hour for Ghaziabad and Allahabad is reflected through graph shown in Fig.2 and sunset hour angle is shown in fig.3 and the value of H_g, H_d for Ghaziabad and Allahabad obtained through various correlation are shown in Table 3 throughout the year.

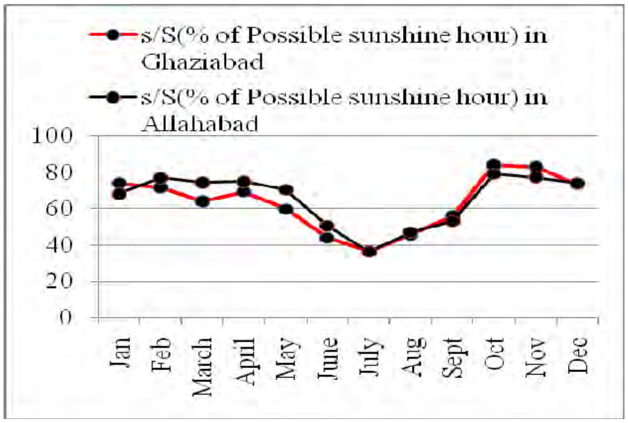

Fig.2 Percentage Possible Sunshine Hour

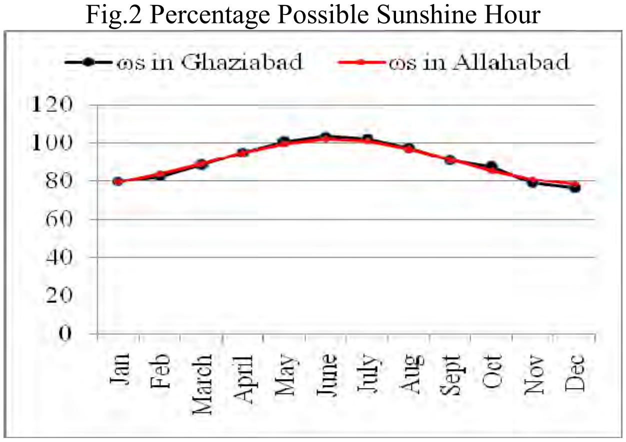

Fig.3 Sunset Hour Angle in Degree

TABLE 1
Input parameters for estimation of monthly average solar radiation in the absence of atmosphere at Ghaziabad and Allahabad, Uttar Pradesh, India

Month	n	δ	ω_s in Ghaziabad	ω_s in Allahabad
Jan	17	-20.9	79.95	79.54
Feb	47	-13.0	82.75	83.70
March	75	-2.40	88.69	88.86
April	105	9.40	95.19	94.52
May	135	18.8	100.73	99.32
June	162	23.1	103.49	101.71
July	198	21.2	102.24	100.63
Aug	228	13.5	97.54	96.56
Sept	258	2.20	91.20	91.05
Oct	288	-9.60	87.70	85.39
Nov	318	-18.9	79.27	80.63
Dec	344	-23.0	76.58	78.35

TABLE 2(a)
Input parameters for estimation of monthly average global solar radiation at Ghaziabad, Uttar Pradesh, India

Month	s (Monthly average sunshine hour)	S(Monthly average day length)	s/S(% of Possible sunshine hour)
Jan	7.8	10.54	74.0038
Feb	8.0	11.15	71.7489
March	7.7	12.01	64.1132
April	8.9	12.84	69.3145
May	8.1	13.56	59.7345
June	6.1	13.93	43.7904
July	5.0	13.76	36.3372
Aug	6.0	13.15	45.6274
Sept	6.9	12.33	55.9611
Oct	9.1	10.83	84.0259
Nov	8.9	10.74	82.8678
Dec	7.6	10.35	73.4250

TABLE 2(b)
Input parameters for estimation of monthly average global solar radiation at Allahabad, Uttar Pradesh, India

Month	s (Monthly average sunshine hour)	S (Monthly average day length)	s/S (% of Possible sunshine hour)
Jan	7.3	10.70	68.2243
Feb	8.6	11.18	76.9231
March	8.9	11.96	74.4147
April	9.5	12.70	74.8032
May	9.4	13.33	70.5176
June	6.9	13.64	50.5865
July	4.9	13.50	36.2963
Aug	6.1	12.97	47.0316
Sept	6..5	12.26	53.0180
Oct	9.1	11.51	79.0617
Nov	8.4	10.87	77.2769
Dec	7.8	10.54	74.0038

TABLE 3(a)
Variation of diffuse Solar Radiation in Ghaziabad and Allahabad, Uttar Pradesh, India

Month	H_d (MJ/m^2-day) in Ghaziabad	H_d (MJ/m^2-day) in Allahabad
Jan	03.82	04.58
Feb	04.90	04.63
March	06.92	05.83
April	07.20	06.51
May	09.27	07.68
June	11.24	10.51
July	11.55	11.43
Aug	10.30	10.22
Sept	08.24	08.75
Oct	03.40	04.54
Nov	02.93	04.04
Dec	03.65	04.03

TABLE 3(b)
Variation of Global Solar Radiation in Ghaziabad and Allahabad, Uttar Pradesh, India

Month	H_g (MJ/m^2-day in Ghaziabad)	H_g (MJ/m^2-day in Allahabad)
Jan	15.05	15.50
Feb	17.84	19.53
March	20.20	22.54
April	24.34	25.52
May	24.25	26.27
June	21.40	22.62
July	19.48	19.43
Aug	20.24	20.64
Sept	19.80	19.73

Oct	20.70	20.81
Nov	16.85	17.23
Dec	14.09	15.34

The value of diffuse solar radiation H_d has larger value during following months of year i.e. February to August from west to east of the state and September to January. It will be Higher values from east to west. The comparison between east to west in H_d is shown in Fig.4 and global solar radiation H_g has higher values throughout the year except than July and September from east to west of the state shown in fig.5. Direct solar radiation H_o data of Ghaziabad and Allahabad which are located in west and east of the state Uttar Pradesh, India respectively shown in Table 4. Monthly variation of H_o in Ghaziabad and Allahabad is shown in fig.6

TABLE 4

Variation of Direct Solar Radiation in Ghaziabad and Allahabad, Uttar Pradesh, India

Month	**H_o (MJ/m^2-day in Ghaziabad)**	**H_o (MJ/m^2-day in Allahabad)**
Jan	22.06	23.93
Feb	26.62	28.20
March	32.07	33.17
April	37.02	37.45
May	39.98	39.82
June	40.98	40.53
July	40.37	40.05
Aug	38.05	38.23
Sept	33.76	34.60
Oct	28.16	29.59
Nov	23.10	24.89
Dec	20.74	22.66

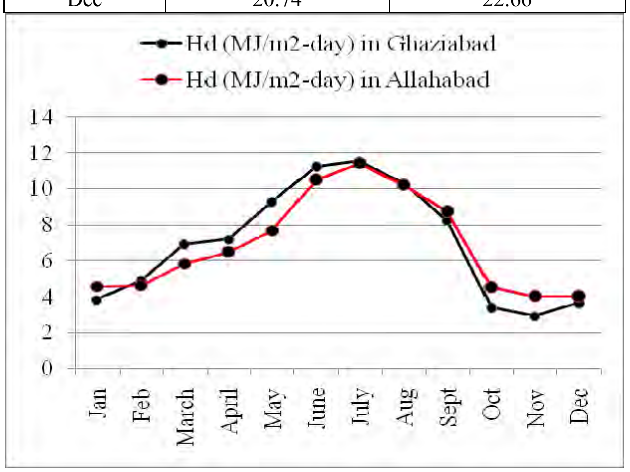

Fig.4 Monthly variation of H_d in Ghaziabad and Allahabad

I. CLEARNESS INDEX

The clearness of the atmosphere is measured by ratio of global radiation to direct or beam radiation that reaches the earth surface. The degree of clearness or Clearness index of the sky is given by the following

$$K_T = H_g / H_o$$

Where K_T is clearness index, H_g is the global solar radiation and H_o is the Direct or Beam solar radiation. From the estimated value of H_g for east to west of the state Uttar Pradesh, India. K_T is calculated and Variation of clearness index in two cities in the state Uttar Pradesh which are located east and west of the state Uttar Pradesh, India shown in table 5. It is very encouraging to note that the sky over east to west is very clear during February to august of the year and rest of the months i.e. September, October, November, December and January more in east region it is about 60% throughout the year with exception of June, August and September which lies

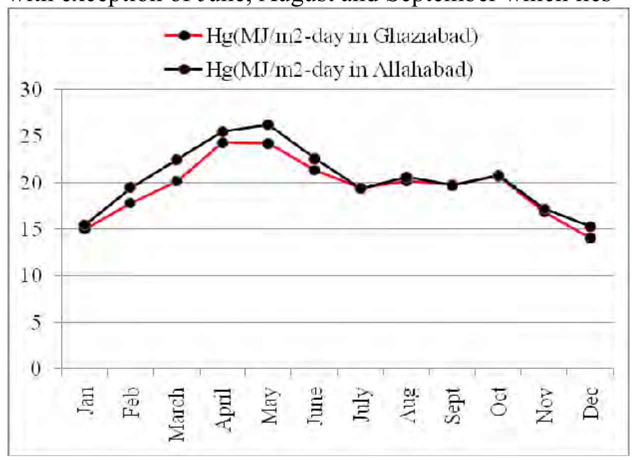

Fig.5 Monthly variation of H_g in Ghaziabad and Allahabad

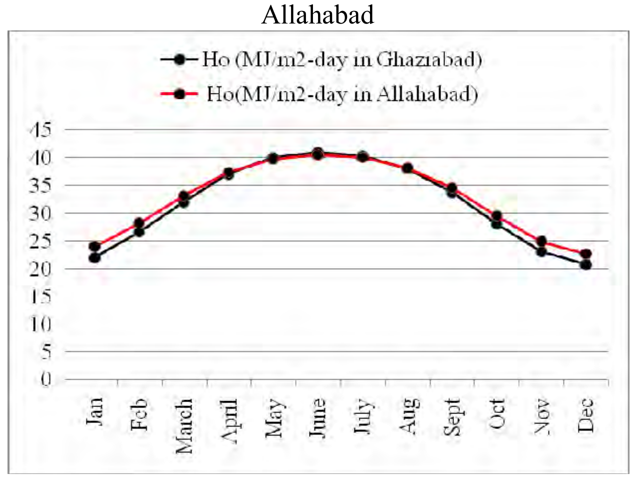

Fig.6 Monthly variation of H_o in Ghaziabad and Allahabad

in between 50% to 60% but month of July it is below 50% (K_T < 0.5) but in the west region it about more than 62% throughout the year. In July month west region of the state Uttar Pradesh it is also below than 50% (K_T < 0.5) shown in fig.7.

TABLE 5

Variation of Clearness index in Ghaziabad and Allahabad, Uttar Pradesh, India

Month	**K_T = Hg/Ho in Ghaziabad**	**K_T = Hg/Ho in Allahabad**
Jan	0.6822	0.6579
Feb	0.6702	0.6923
March	0.6299	0.6795
April	0.6575	0.6815
May	0.6066	0.6596

June	0.5222	0.5580
July	0.4825	0.4851
Aug	0.5319	0.5399
Sept	0.5865	0.5704
Oct	0.7351	0.7032
Nov	0.7295	0.6941
Dec	0.6794	0.6770

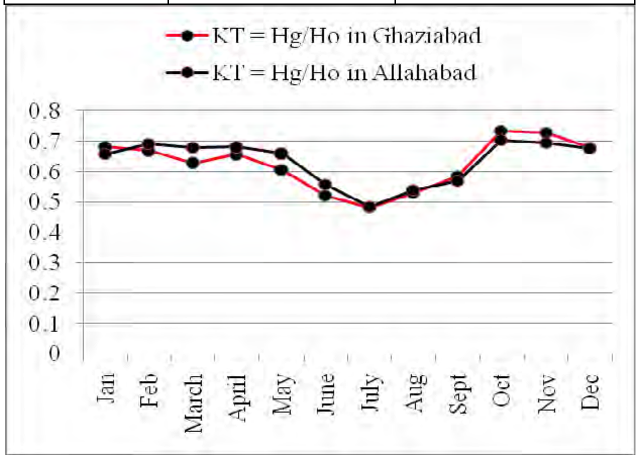

Fig.7 Monthly variation of clearness index K_T

II. CONCLUSION

In this paper, after conversion process utilization of solar energy has bright prospective future in much more in eastern area as compare to western area of the state Uttar Pradesh, India. The global radiation component reveals that solar radiation can be very efficiently used by after conversion process to compensate for the energy deficit in the east region of the state throughout the year except than July and September because during the months July and September global solar radiation is slightly more than in west region .

Using Liu and Jordan method [5] is in excellent agreement for the calculation of diffuse radiation. whereas Angstrom equation calculates the monthly average daily global solar radiation by substituting the value of H_o. This analysis can be very helpful to use these energy resources at destination east region and west region of the state, Uttar Pradesh, India. Entire experimental data are obtained of direct, global and diffuse solar radiation with the help of the illustrated equations (1),(2),(3),(4),(5),(6) and (7) which are shown in Table 1,Table 2,Table 3, Table 4 and Table 5 available for destinations. The estimation has to be done employing sunshine hours of the location. Different nature of regression could be developed, now the measured data for the destination under study is available. With the help of measured data may be very helpful in future that what place be chosen for installation of plant by conversion process to solve energy crises in state.

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