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Estimation of Solar Irradiance at Gorakhpur Workstation

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Abstract- This research relates to the estimation and analysis of Solar radiation at Gorakhpur work station located in East of Uttar Pradesh India having longitude 83.3732 (83° 22' E) and latitude 26.7606 (26° 45' N). The solar radiation energy which varies according to geographical location and weather conditions depends upon variation of solar radiation Global and Diffuse components excepting rainy season from month of June to September every year. The diffuse components of solar radiation are found to be very large and the solar energy available in the region is quite in abundance. This work estimates variation in the solar components of entire solar radiation and explores possible deployment of available solar radiation energy for conversion through solar panels and possible to reduce the energy crisis at this region.

Index Terms- Solar irradiance, Global radiation, Diffuse radiation, Workstation

I. INTRODUCTION

Gorakhpur district has augmented its capacity with two main sub-stations of 400/220 KV, supplying 315 MVA and 500 MVA load which caters to the needs of residential, commercial and industrial consumers. Inspite of this increase in the electricity infrastructure and may fail to provide increasing demand for electricity. This study, therefore, aims to estimate solar radiation energy available in the Gorakhpur city fig.1 and explore possibility of its conversion into electric energy and contribute in providing solution of the energy crises prevailing in the State.

II. ESTIMATION OF RADIATION

Sunshine hour and duration are the most commonly used parameters for estimating global solar radiation. Sunshine duration is to be taken for a given period in which the direct solar radiation exceeds 120W per square meter. Solar radiation intensity is taken as incoming radiation of short-wave length measured in MJ/m²-day. Sunshine duration can be measured and the relevant data is readily available from the Weather Stations. Majority of the models relating to the estimation of global solar radiation are based on the sunshine ratio (s/S) that helps in the prediction of monthly average daily global radiation. Angstrom- Prescott model, Ogelman model and Samuel model for the purpose of estimating global radiation considered for the process.

Fig.1

Angstrom – Prescott model: This is the most commonly used model as per the relation,

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

Where H_g is the global solar radiation, H_0 is the extraterrestrial solar radiation, s is the mean sunshine hour and S is the mean sunshine duration, a and b are empirical coefficients.

Ogelman model: Following equation has been presented by Ogelman for estimating global solar

Radiation

$$\frac{H_g}{H_o} = a + b\left[\frac{\bar{s}}{\bar{S}}\right] + c\left[\frac{\bar{s}}{\bar{S}}\right]^2 \quad (2)$$

Where a,b and **c** are empirical coefficients. This is a second order equation and is quadratic in nature.

Samuel model: Samuel estimated global solar radiation on a horizontal surface by the following equation

$$\frac{H_g}{H_o} = a + b\left[\frac{\bar{s}}{\bar{S}}\right] + c\left[\frac{\bar{s}}{\bar{S}}\right]^2 + d\left[\frac{\bar{s}}{\bar{S}}\right]^3 \quad (3)$$

Where a,b,c and d are empirical coefficients.

The variation in the coefficient of determination is only 0.19% which is too insignificant a variation due to change in the order of polynomial. So, in this paper only the Angstrom-Prescott model based on sunshine parameters is considered for estimating the global radiation.

The aim of this Paper is to Estimate the Global, direct and diffuse solar radiation on a horizontal surface at a given location which can be obtained by different equations developed by researchers from time to time .The ratio s/S is often called the percentage of possible sunshine hour in the angstrom-Prescott equation. Climatologically regression coefficient can be calculated using different models available in the literature. The regression coefficients of Angstrom equation a and b depend on the seasonal parameters. Even though other methods are available, this work evaluates regression coefficients [4] using relations given in equations (4) and (5) below:

$$a = -0.110 + 0.235\cos\phi + 0.323\left(\frac{\bar{s}}{\bar{S}}\right) \quad (4)$$

$$b = 1.449 - 0.553\cos\phi - 0.694\left(\frac{\bar{s}}{\bar{S}}\right) \quad (5)$$

Duffi and Beckman [12] have derived equation (6) which is applied to determine H_o for Gorakhpur district in the State of Uttar Pradesh, India as,

$$H_0 = \frac{24\times 3600}{\pi} G_{SC}\left[1+0.033\cos\left(\frac{360n}{365}\right)\right] \times \left(\sin\omega_S\cos\delta\cos\phi + \left(\frac{\pi\omega_S}{180}\right)\sin\phi\sin\delta\right) \quad (6)$$

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

Solar declination can be calculated using equation (7) as,

$$\delta = 23.45\sin\left[\frac{360(284+n)}{365}\right] \quad (7)$$

Sunset hour angle can be calculated by the equation (8)

$$\cos\omega_S = -\tan\phi\tan\delta \quad (8)$$

Krieth developed the empirical expression to estimate the diffuse component of solar radiation which correlates the diffuse solar radiation H_d to the daily total radiation H_o. This is expressed below in equation (9)

$$\frac{H_d}{H_g} = 1.411 - 1.696\left(\frac{H_g}{H_o}\right) \quad (9)$$

III. ESTIMATED COMPONENTS

The entire set of input parameters for estimating both, monthly average daily solar radiation H_o in the absence of atmosphere and monthly average daily global solar radiation H_g at Gorakhpur East of the State of Uttar Pradesh, India is given in Table 1 and Table 2. It is clearly seen that percentage possible sunshine hour is about 61.37% throughout the year. Substitution of the regression coefficient "a" and "b" is illustrated in Angstrom equations for estimation of the monthly average daily global solar radiation H_g. The percentage possible sunshine hour for Gorakhpur is reflected in the graph of Fig. 2 and sunset hour angle is shown in fig. 3. The value of H_0, H_g, and H_d for Gorakhpur city are obtained using various equations for each month of the year are indicated in Table 3.

TABLE 1

Month	n (nth day of the months)	δ (solar declination in degree)	ω_s (sunset hour angles in degree)
January	17	-20.9	78.90
February	47	-13.0	83.31
March	75	-2.40	88.79
April	105	9.40	94.79
May	135	18.8	99.88
June	162	23.1	103.62
July	198	21.2	101.27
August	228	13.5	96.95
September	258	2.20	91.11
October	288	-9.60	85.11
November	318	-18.9	80.06
December	344	-23.0	77.65

Input parameters for estimation of monthly average solar radiation in the absence of atmosphere Gorakhpur, Uttar Pradesh, India

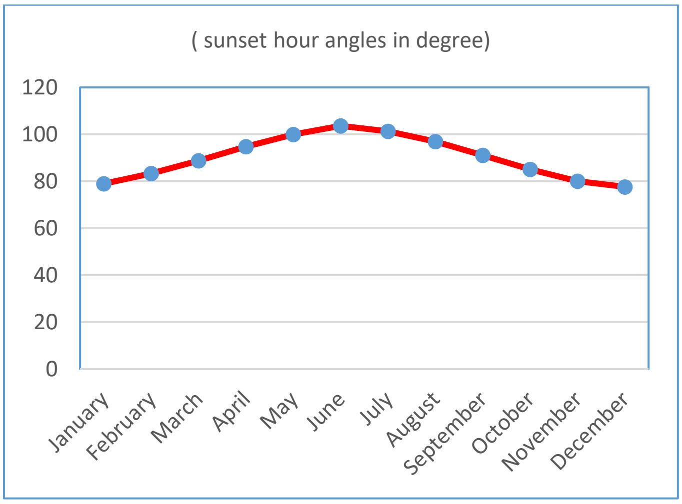

Fig.2 Sunset Hour Angle in Degree

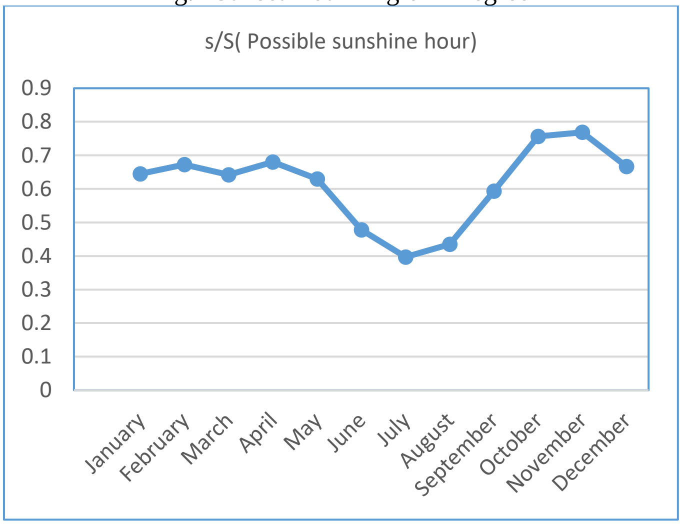

Fig.3 Possible sunshine hour

TABLE 2

Input parameters for estimation of monthly average global solar radiation at Gorakhpur, Uttar Pradesh, India

Month	s (Monthly average sunshine hour)	S(Monthly average day length)	s/S(Possible sunshine hour)
January	6.9	10.7	0.6449
February	7.6	11.3	0.6726
March	7.7	12.0	0.6417
April	8.7	12.8	0.6797
May	8.5	13.5	0.6297
June	6.6	13.8	0.4783
July	5.4	13.6	0.3971
August	5.7	13.1	0.4351
September	7.3	12.3	0.5935
October	8.7	11.5	0.7565
November	8.3	10.8	0.7685
December	7.0	10.5	0.6667

TABLE 3

Entire solar radiation data for Gorakhpur, Uttar Pradesh, India

Month	a	b	H_o	H_g	H_d	K_T (H_g/H_o)
Jan	0.31	0.51	22.25	14.22	4.65	0.6351
Feb	0.32	0.49	26.49	17.21	5.32	0.6497
March	0.31	0.51	32.68	20.23	7.31	0.6190
April	0.32	0.48	36.55	23.62	7.44	0.6462
May	0.31	0.52	41.41	26.40	8.71	0.6375
June	0.26	0.62	40.85	22.74	10.62	0.5567
July	0.23	0.68	42.50	21.25	11.96	0.5000
Aug	0.24	0.65	39.49	20.65	10.82	0.5229
Sept	0.29	0.54	33.34	20.35	7.65	0.6104
Oct	0.34	0.43	29.10	19.36	5.47	0.6653
Nov	0.35	0.42	24.36	16.39	4.42	0.6728
Dec	0.32	0.49	21.97	14.21	4.46	0.6468

Where H_o, H_g and H_d are in MJ/m2-day.

The value of diffuse solar radiation (H_d) is approximately the same during the from. June to August or May and September while global radiation (H_g) is almost equal in the months of March and August in the year. The comparison between H_d, H_g and H_o is shown in Fig 4.

IV. SKY WEATHER

Clearness of the sky is the ratio of global solar radiation to direct solar radiation that reaches the earth surface. It is generally known as a measure of the degree of clearness of the sky. Clearness index is given as

$$K_T = H_g/H_o \quad (10)$$

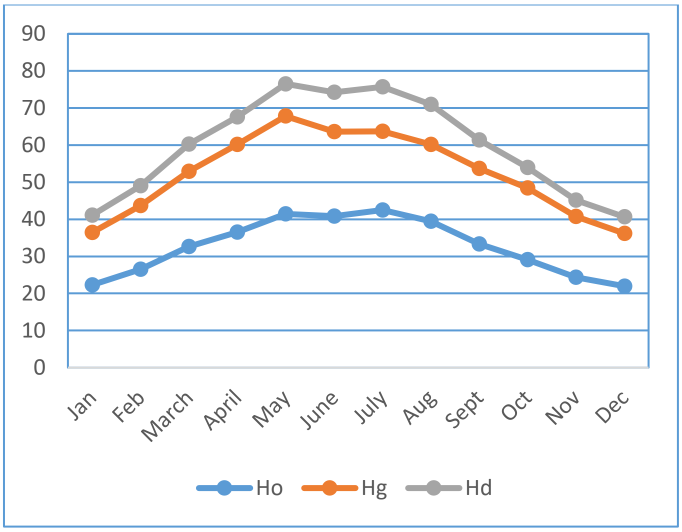

Fig.4 Monthly variation of H_d, H_g, H_o for Gorakhpur

Where K_T is the clearness index. From the calculated value of global radiation for Gorakhpur K_T is calculated. It is encouraging to observe that the sky over Gorakhpur is very clear almost more than 61% of the year with the exception of June, July and August during which it lies between 50% to 55%, but in the months of July 50% (K_T = 0.50). From the calculated value of clearness index it is clearly seen that in the month of November the maximum sky is maximum clear as shown in fig.5

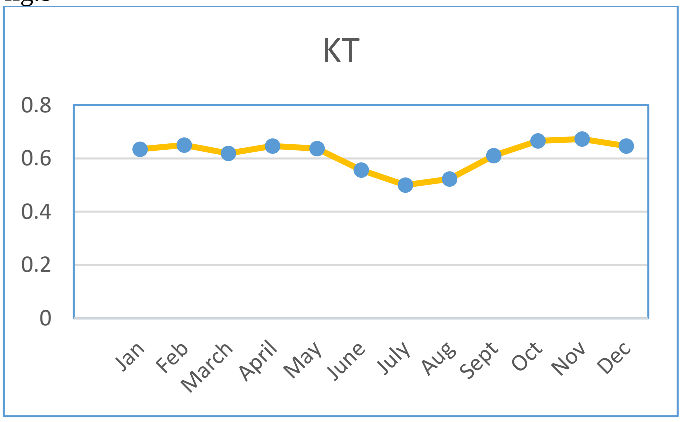

Fig.5 Monthly variation of clearness index K_T

V. CONCLUSION

In this paper, the estimated global solar radiation can be very efficiently converted into electrical energy. After conversion process to compensate the energy demand in the selected work station of the State throughout the year. Using Liu and Jordan method [5] diffuse radiation and also using Angstrom equation direct radiation is to be estimated respectively at destination Gorakhpur, Uttar Pradesh, India. Entire components of solar radiation are obtained the illustrated equations (1) to (9) which are shown in Table 1, Table 2 and Table 3 available for destinations. After estimated global radiation, we have converted it into expected electrical generation. It may be very helpful in future to sort out energy demand at this work station Gorakhpur, Uttar Pradesh, India.

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