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Empirical Model for the Estimation of Solar Radiation at Destination Shegaon, Maharashtra, India.

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Abstract - For solar-based renewable energy technologies as solar photovoltaic or thermal conversion systems, the basic resource or fuel available is solar radiation. Measurement of solar radiation is important for the evaluation and deployment of solar renewable energy systems. In order to calculate the amount of solar radiation falling on a collector at a given time and location, the beam or diffuse radiation should be either measured or estimated using empirical equations. Due to economic reason, it is not possible to measure the solar radiation for all location. Therefore, often it is required to estimate the radiation from the empirical relations. Through the relationships are not completely empirical, they use the parameters that are based on measured meteorological data. This paper describes the empirical technique to estimate the solar radiations for given location. Calculation suggests the proper estimation and more efficient utilization solar radiation on earth surface.

Keywords: Solar radiation, Extraterrestrial radiation, Beam radiation, Diffuse radiation, Sunshine hours, Sky clearness index.

I. INTRODUCTION

Solar energy is the most considerable and important renewable energy source in the world because of its easy availability, cheap and cleanness resources. Sun, which is 1.495 x 10^{11} m far from the earth and has a diameter of 1.39 x 10^{9} m. Sun emit approximately 1367 W/m^2 solar energy on to a surface perpendicular to rays, if in the absence of atmospheric layer. The world receives total 170 trillion KW solar energy. From the total energy received 30% energy reflected back in the space, 47% transformed in to low temperature heat energy, 23% for evaporation/rainfall cycle in the biosphere and less than 0.5% is used in the photosynthesis of plants, kinetic energy of the wind etc.

India had large potential for renewable energy, an estimated aggregate of over 100,000 MW. Blessed with more than 300 sunny days in a year and receiving an average hourly radiation of 200 MW/km^2, India is well placed to overcome its key challenges by utilizing the enormous solar energy potential. Around 12.5% of India’s land mass could be used for harnessing solar energy. In recent years Govt. of India strongly promoted solar energy as a viable energy source. The scope for PV power generation and thermal applications using solar energy is huge in India.

There are a different variety of technologies that have been developed to take benefit of solar energy. But the facilities for solar radiation measurement are available only in few locations in the country due to lack of measuring equipment and techniques involved. Technology for measurement of solar radiation is expensive and problematic therefore, there in need to use some empirical relations to calculate solar radiations from some measured meteorological parameters, such as relative sunshine hours, latitude and Longitude of the site.

Various models are available for estimating solar radiation by using relative sunshine durations and other meteorological data. Angstrom was developing first model and subsequently; other models were developed.

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In India several researches have been carried out for estimating solar radiation at different locations. However, none has been found in the literature of the models developed for estimating solar radiation for Shegaon and its environs of similar meteorological parameters. The aim of the work is to develop an Angstrom-type of empirical model for the estimation of global solar radiation for Shegaon and other surrounding towns. Shegaon is located at Buldhana district of Maharashtra state India, latitude 20º46' 47.91" N - Longitude: 76º40' 45.12" E. Shegaon is noted for the temple of Shri Sant Gajanan Maharaj, SSGM College of Engineering and Solar Research Centre.

This work will help to take advantage of solar energy potential to solve the energy problems in the state. The sunshine hour data and related data used in this research were obtained from Solar Research Centre Shegaon.

II. SOLAR SPECTRUM AT THE EARTH'S SURFACE

Earth continuously receives about 170 trillion KW of incoming solar irradiation at the upper atmosphere. The solar radiation just outside the earth's atmosphere is known as extraterrestrial solar radiation. The total energy intensity of extraterrestrial solar radiation and integrated over the entire solar spectrum, is called solar constant. The intensity and spectral distribution of solar radiation are considerably altered by the earth’s atmosphere. The principle mechanism causing atmospheric alterations of solar radiation are absorption and scattering, including reflection. Atmospheric scattering of solar radiation has a particularly important consequence: it separate the solar radiation into direct and diffuse components.

The interaction between solar radiations in earth's atmosphere is shown in Figure 1. The some of the solar radiation absorbed by the gaseous molecules and other particles in the atmosphere. It is a loss of solar radiation. Those radiations reaches the earth surface directly, without go through either absorption interaction or scattering interaction and is known as direct or beam radiation. Once the radiation reaches the earth's surface some of it gets reflected by the ground called albedo radiation and other objects on the ground. Thus, the total radiation reaching at a certain point on the earth surface is the sum of the direct, diffuse and albedo radiation known as global radiation. For a normal sunny day diffuse radiation is about 15% to 20% of the beam solar radiation.

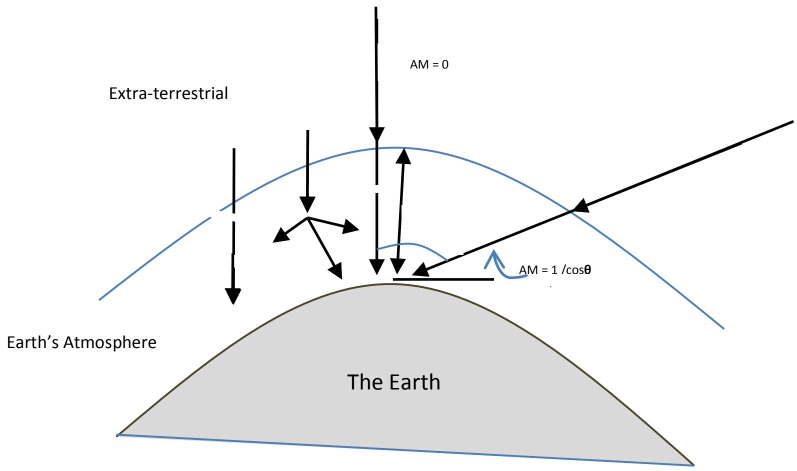

Fig 1: Interaction of Solar Radiation in Earth's Atmosphere (AM = air mass).

In solar radiation spectrum mainly consists of visible and infrared radiation. The UV component in the spectrum is small. The distribution of solar spectrum on the earth's surface is given in Table 1.

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Table 1: Solar spectrum on the earth's surface

Type of radiation	Range of wavelengths (nm)	% of energy carried
Ultraviolet Radiation	150 to 380	7.6
Visible radiation	380 to 720	48.4
Infrared radiation	720 to 4000	43
Other radiation	➢ 4000	1

III. METHODOLOGY

The Angstrom- Prescott regression equation which has been used to estimate the monthly average daily solar radiation on a horizontal surface is given as,

$$\frac{Hg}{Ho} = a + b\,\frac{Sa}{Sp}$$

Where,

H_g = monthly or weekly average of the daily global radiation on a horizontal surface (KJ/m^2 day)

H_o = monthly or weekly average of the daily extraterrestrial radiation on a horizontal surface (KJ/m^2 day)

S_a = monthly or weekly average of duration of actual sunshine hours (h)

S_p = monthly or weekly average of duration of possible sunshine hours (h)

a and b = regression constant to be determined.

The value of the monthly average daily extraterrestrial irradiation (H_o) can be calculated from the following equation, (Duffie and Beckman, 1991)

$$Ho = \frac{24}{\pi} I_{sc}\left(1 + 0.33 \cos\frac{360\,n}{365}\right)(\cos\Phi \cos\delta \sin\omega_s + \omega_s \sin\Phi \sin\delta)$$

Where,

I_{sc} = solar constant = 1367 W/m^2, Φ = Latitude of the site, δ = solar declination, ω_s = mean sunrise hour angle for the given month, n = number of days of the year starting from the first of January.

The solar declination (δ) and the mean sunrise hour angle (ω_s) can be calculated by the following equations respectively,

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

$$\omega_s = \cos^{-1}(-\tan\Phi\ \tan\delta)$$

'n' for the mean day of the month as proposed by Klein. Klein suggested the values of 'n' to be taken as n=17 (Jan 17), 47 (Feb 16), 75 (March 16), 105 (April 15), 135 (May 15), 162 (June 11), 198 (July 11), 228 (August 16), 258 (Sep.15), 288 (Oct.15), 318 (Nov.14) and 344 (Dec.10). The suggested values of 'n' give satisfactory representative average value of declination for the month.

For a given month, the maximum possible sunshine duration monthly average day length (S_p) which is related to ω_s, the mean sunrise hour angle can be computed by using the following equation (Duffie)

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$$S_p = \frac{2}{15}\omega s = \frac{2}{15}\cos^{-1}(-\tan\Phi\ \tan\delta)$$

Regression coefficient 'a' and 'b' have been obtained from the relationship given as equation.

$$a = -0.110 + 0.235\cos\Phi + 0.323\,(S_a / S_p) = -0.110 + 0.235\cos 20.46 + 0.323\,(0.625) = 0.31$$

$$b = 1.449 - 0.553\cos\Phi - 0.694\,(S_a / S_p) = 1.449 - 0.553\cos 20.46 - 0.694\,(0.625) = 0.50$$

The model constant, **a** and **b** obtained in this investigation were 0.31 and 0.50 respectively. Hence the first order polynomial developed for Shegaon is

$$\frac{Hg}{Ho} = 0.31 + 0.50\,\frac{Sa}{Sp}$$

The diffuse radiation H_d, can be estimated by an empirical formula below. For Indian stations where the diffuse radiation is much higher compared to US stations, the linear correlations as proposed by Modi and Sukhatme and Gupta et.al respectively:

$$\frac{Hd}{Hg} = 1.411 - 1.696\,\frac{Hg}{Ho}$$

IV. RESULT AND ANALYSIS

The input source parameter for estimating monthly daily solar radiation H_o in the absence of atmosphere and also estimating of monthly average daily global solar radiation H_g in the year of 2015 at Shegaon, Maharashtra, India is shown in table 2 and 3. With reference of this it is observed that percentage possible sunshine hour is about 62.5 percent throughout the year.

Table 2: Input source parameter for estimating of monthly average solar radiation in the absence of atmosphere at Shegaon, Maharashtra, India

Month	Date of Month	I_{sc} (solar constant in W/m^2)	n (n^{th} of the day of the months)	δ (solar declination in degree)	ω_s (sunset hour angle in degree)
January	17	1367	17	-20.91	81.8
February	16	1367	47	-12.95	85.07
March	16	1367	75	-2.42	89.09
April	15	1367	105	9.41	93.54
May	15	1367	135	18.79	97.29
June	11	1367	162	23.08	99.14
July	17	1367	198	21.18	98.31
August	16	1367	228	13.45	95.12
September	15	1367	258	2.22	90.83
October	15	1367	288	-9.6	86.38
November	14	1367	318	-18.91	82.65
December	10	1367	344	-23.05	80.86

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Table 3: Input parameter for estimating of monthly average global solar radiation at Shegaon, Maharashtra, India

Month	S_a (Monthly average sunshine hour)	S_p (Monthly average day length)	S_a/S_p (% of possible sunshine hour)
January	8.8	10.91	80.66
February	8.9	11.34	78.48
March	9.1	11.88	76.6
April	9.6	12.47	76.98
May	9.7	12.97	74.79
June	5.3	13.21	40.12
July	3.2	13.11	24.41
August	3.6	12.68	28.39
September	5.7	12.11	47.07
October	7.9	11.52	68.58
November	8.3	11.02	75.32
December	8.5	10.78	78.85

Table 4: Entire Solar Radiation Data of year 2015 for Shegaon, Maharashtra, India

Month	H_o (KJ/M^2-day)	H_g (KJ/M^2-day)	H_d (KJ/M^2-day)	$K_T = H_g/H_o$
January	26688.73	19037.07	3831.08	0.713299958
February	30507.4	21428.39	4708.45	0.702399746
March	34655.2	24016.05	5663.98	0.692999896
April	37895.5	26333.58	6125.69	0.694899922
May	39355.62	26917.27	6759.07	0.68394984
June	39640.1	20240.24	11031.38	0.510600125
July	39352.3	17002.16	11533.04	0.432049969
August	38278.7	17300.05	11151.22	0.451949779
September	35682.2	19459.28	9460.54	0.545349782
October	31608.2	20636.99	6270.57	0.65289988
November	27517.89	18893.78	4657.81	0.686599881
December	25502	17959.78	3890.25	0.704249863

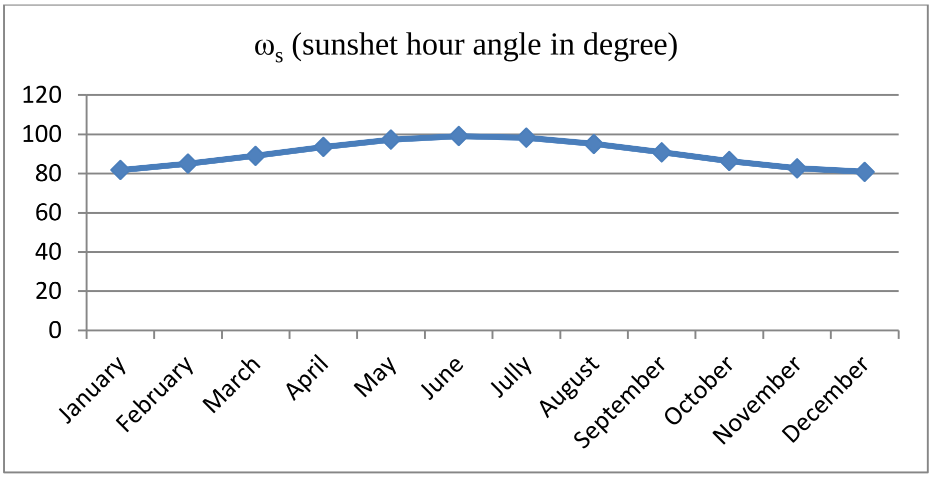

Fig.2: Sunset Hour Angle in Degree

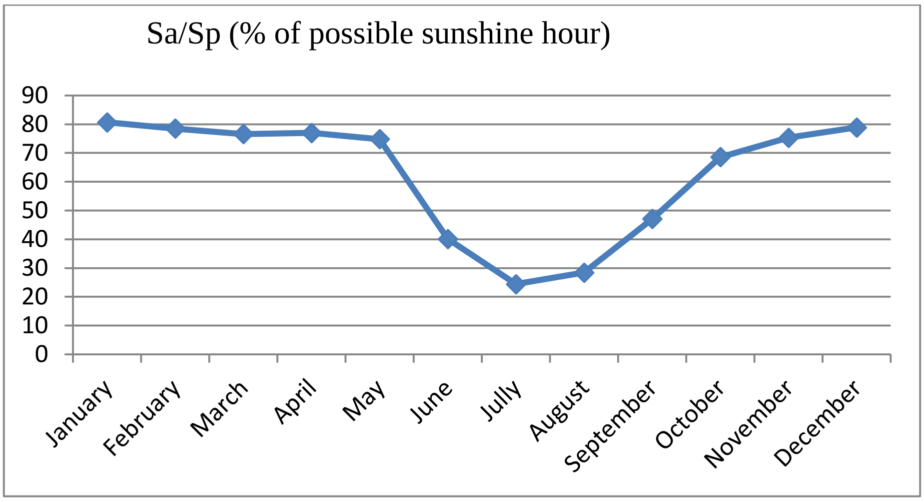

Fig. 3: Percentage Possible Sunshine Hour

The value of diffuse radiation (H_d) has approximately almost equal value during following months of year i.e. June, July and August. The comparison between H_d, H_g, H_o is shown in Figure 4.

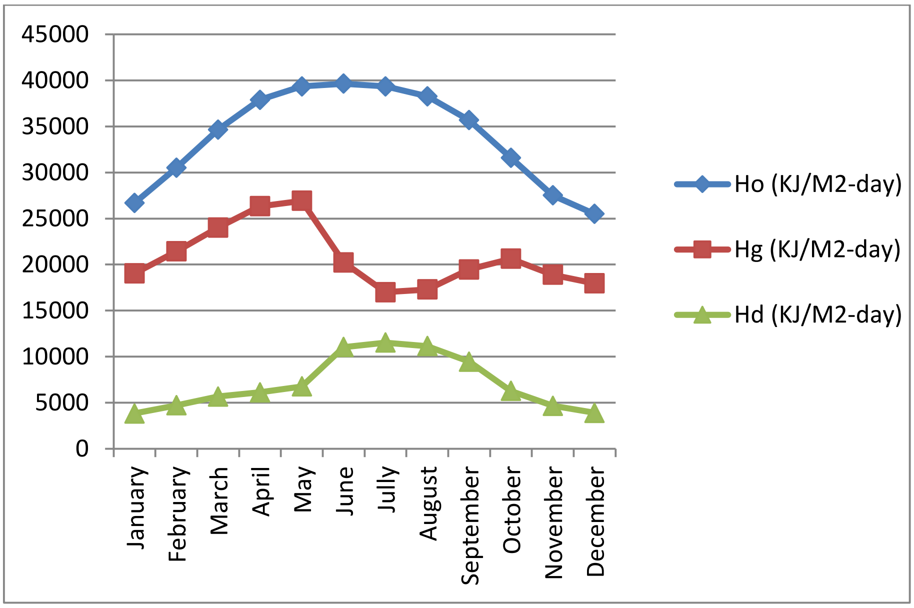

Fig.4: Monthly variation of H_d, H_g, H_o for Shegaon, Maharashtra, India

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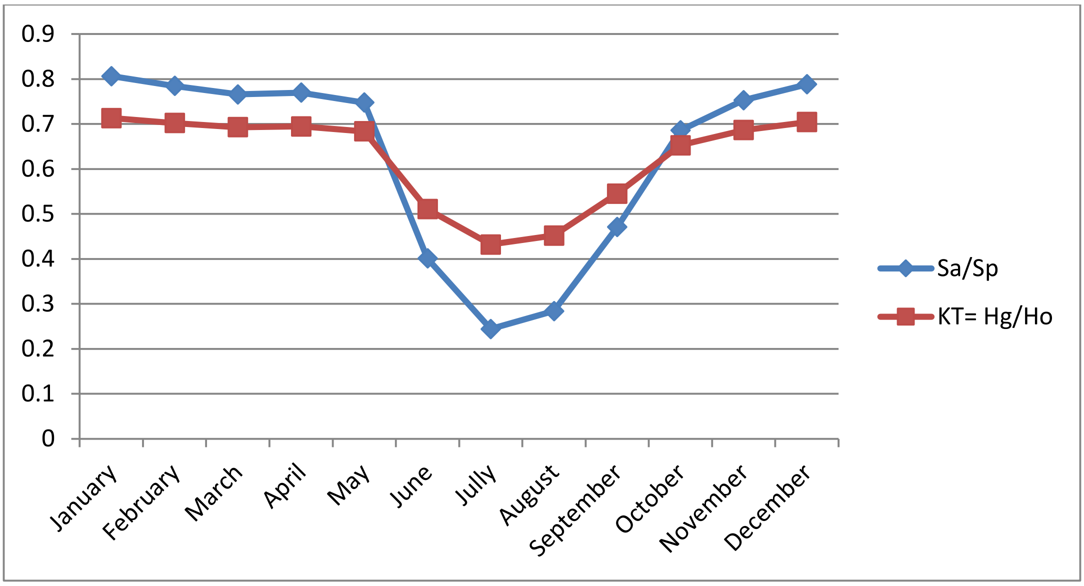

Fig.5: Relationship between the relative sunshine duration (S_a/S_p) and clearness index (K_T) for Shegaon, Maharashtra, India

Figure 5 shows the relationship between the relative sunshine duration (S_a/S_p) and clear sky index (K_T). The value of K_T (= 0.4320) corresponding to the lowest value of S_a/S_p (=0.2441) and Hg (= 17002 KJ/M^2-day) in the month of July indicate poor sky conditions. These conditions correspond to the wet or rainy season (June-September) observed in Shegaon, Maharashtra, India, during which there is much cloud cover.

V. CONCLUSION

This paper gives exact solution for determining the empirical technique for estimating the solar radiation energy which includes monthly averaged daily global, diffuse, extraterrestrial radiation and monthly averaged daily sunshine hours and maximum possible daily sunshine hours(day length) at a given location With the help of this technique, the solar radiations on the earth surface for solar power generation at a particular place can be calculated which is helpful to solve energy crises in future.

REFRENCES

I. A. Angstrom " Solar and terrestrial radiation" Q.J.R.Meteoral.Soc.1924,50,121-125
II. S. A. Klein, "Calculation of monthly average insolation on tilted surface". Solar Energy, 1977, 19,325.
III. J.A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, John-Wiley & Sons, New York, 1991
IV. J. F. Kreider and F. Kreith , Solar Energy Handbook(Chapter 2), McGraw-Hill, New York, 1978
V. Vijay Modi and S.P. Sukhatme, " Estimation of Daily total and diffuse insolation in India from whether data" solar energy, 1979,22,407
VI. H. P. Garg and J.Prakash, Solar energy- Fundamental and Applications (Chapter 1), Tata McGraw Hill Education Private Limited, New Delhi,1997