ESTIMATION OF DAILY DIFFUSE SOLAR RADIATION IN KHORASAN PROVINCE, IRAN

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Abstract: - Applying the measured global and diffuse solar radiation data from meteorological station in Khorasan, Iran, a province wide correlation model for calculating the daily diffuse radiation was derived on the basis of Erbs et Al and collares-Pereira .In this study, the monthly average daily diffuse radiation on a horizontal surface ($\overline{H}_d$) and the monthly average daily radiation on a horizontal surface for the location ($\overline{H}$) have been measured for over ten years and a correlation between ($\overline{k}_T$) and ($\overline{H}_d / \overline{H}$) or ($\overline{H} / \overline{H}_o$) have been derived.

The two most important statistics Root Mean Square Error (RMSE) and Mean Bias Error were used to assess the performance of the correlation. We develop in this study a correlation to estimate the monthly average daily diffuse radiation on horizontal surface in Khorasan province.

Key-Words: - Global and diffuse solar radiation, Meteorological data,

1 Introduction

The Islamic Republic of Iran with more than 70 million populations is one of the most energy consumers. Its energy is based on fossil fuel. Because of the existence of petroleum and natural gas, a few experts are studying in solar energy and other kind of renewable energy. It's very important to know that the average number of clear sky day in Iran is 300 days per year. Except in the north and parts of northwest regions, which have partially cloudy skies, all other parts of Iran have a very warm bright sunshine during the 9 months a year.

Construction of a solar power plant needs a large amount of investment, but according to the amount of solar radiation and the free source of this kind of energy, it will be a good investment.

The most important parameters to design a solar system or a solar power plant are the component of the solar radiation. We can measure total radiation in a region but the measurement of the beam radiation is the solution of a solar system because solar systems always design according to the amount of beam radiation.

The advantages of a solar systems or power plants are:

1. the source of this energy is free
2. no environment pollution
3. no infected gas
4. no wear of machinery

Meteorological data are the best source of information for estimation average incident radiation. Lacking these or data from nearby location of similar climate it is possible to use empirical relation from hours of sunshine or cloudiness. The original Angstrom- type regression equation related monthly average daily radiation to clear day radiation at the location in question and average fraction of possible sunshine hours:

$$\overline{H} / \overline{H}_o = a + b\left(\frac{\overline{n}}{\overline{N}}\right) \quad (1)$$

$$\overline{H}_o = \frac{24 \times 3600 \times G_{sc}}{\pi}\left(1 + 0.033\cos\frac{360n}{365}\right)\left(\cos\phi\cos\delta\sin\omega_s + \frac{\pi\omega_s}{180}\sin\phi\sin\delta\right) \quad (2)$$

n = the day of the year
$\overline{H}$ = monthly average daily radiation on a horizontal surface
$\overline{H}_o$ = the extraterrestrial radiation for the location
a,b = Empirical constant
$\overline{n}$ = monthly average daily hours of bright sunshine
$\overline{N}$ = monthly average of the maximum possible daily hours of bright sunshine (i.e., the daily length of the average day of the month)
G_{sc} = the solar constant

2 Estimation of average solar radiation

$$\overline{N} = \frac{2}{15}\cos^{-1}\left(-\tan\phi\tan\delta\right) \quad (3)$$

The empirical constant in this equation are depended on climate and vegetation condition of the area [1]. For example n this study we can assume a=0.34, b= 0.42 for Mashhad.

3 Beam and diffuse components of monthly radiation

The distributions of monthly average daily radiation into its beam and diffuse components have been derived by Collares-pereira and Rabl. (4)

$$\frac{\overline{H}_d}{\overline{H}} = 0.775 + 0.00606(\omega_s - 90) - [0.505 + 0.00455(\omega_s - 90)]\cos(115\overline{k}_T - 103) \quad (4)$$

Where ω_s and $\overline{k}_T$ are the independent parameters and ω_s is the sunset hour angle in degree.

$$\omega_s = \cos^{-1}\left(-\tan\phi\tan\delta\right) \quad (5)$$

ϕ is latitude, δ is declination which comes from the below equation:

$$\delta = 23.45\sin\left(360\frac{284+n}{365}\right) \quad (6)$$

And also Erbs et al developed monthly average diffuse fraction correlation from the daily diffuse correlations:

$$\frac{\overline{H}_d}{\overline{H}} = 1.391 - 3.560\overline{k}_T + 4.189\overline{k}_T^{\,2} - 2.137\overline{k}_T^{\,3} \quad (7) \quad \begin{cases} 0.3 \le \overline{k}_T \le 0.8 \\ \omega_s \le 81.4^\circ \end{cases}$$

$$\frac{\overline{H}_d}{\overline{H}} = 1.311 - 3.022\overline{k}_T + 3.422\overline{k}_T^{\,2} - 1.821\overline{k}_T^{\,3} \quad (8) \quad \begin{cases} 0.3 \le \overline{k}_T \le 0.8 \\ \omega_s > 81.4^\circ \end{cases}$$

4 Correlation and discussion

With the measured data of global and diffuse radiation on a horizontal surface and the hours of bright sunshine, as well as the data of the geographic and meteorological parameters in Khorasan province, the auto-correlation method of polynomial are conducted.

The first step of calculation is δ , for all months and N in equation (6) is the average day of the month.

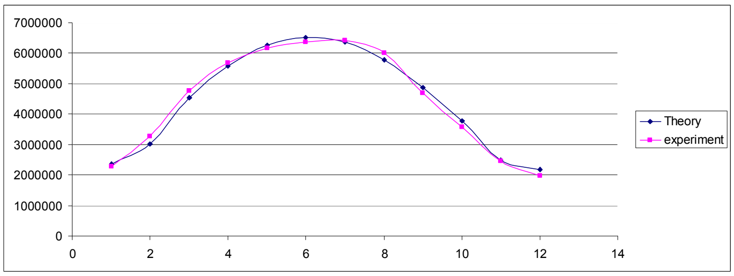
Table (1) shows the results:

month	N	declination
jan	17	-20.9
feb	47	-13
mar	75	-2.4
apr	105	9.4
may	135	18.8
jun	162	23.1
jul	198	21.2
aug	228	13.5
sep	258	2.2
oct	288	-9.6
nov	318	18.9
dec	344	-23

Table (1)

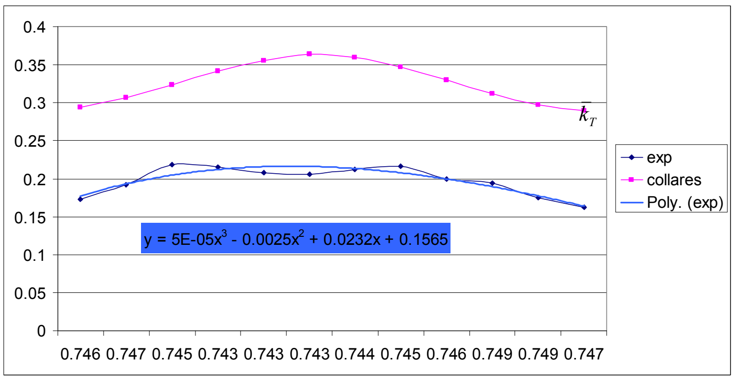
It's known that the latitude of Mashhad in Khorasan province is 36. In this way $\overline{k}_T$, ω_s can be calculated from equations (1), (5) and $\overline{H}_d/\overline{H}$ from equations (4), (7) or (8) and the results are shown in below diagrams.

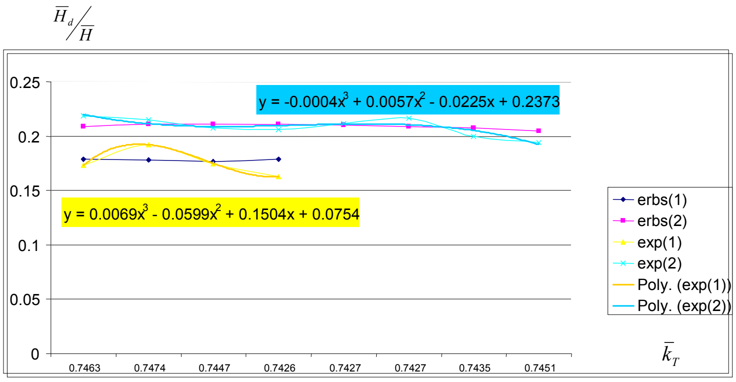
$\overline{H}_d \; J/m^2$



Month

$\overline{H}_d/\overline{H}$





5 Conclusions

Whit the measured data of global and diffuse radiation on a horizontal surface and the hours of bright sunshine, as well as the relevant data of the geographic and meteorological parameters, in Khorasan province, various correlation between the monthly average daily diffuse radiation on a horizontal surface and the relative duration of bright sunshine have been developed.
The following two correlations which used to estimate the monthly average daily diffuse radiation on a horizontal surface are recommended.

$$\bar{H}_d/\bar{H} = -0.0004\bar{k}_T^{\,3} + 0.0057\bar{k}_T^{\,2} - 0.0225\bar{k}_T + 0.2373 \qquad \begin{cases} 0.3 \le \bar{k}_T \le 0.8 \\ \omega_s > 81.4^\circ \end{cases}$$

$$\bar{H}_d/\bar{H} = 0.0069\bar{k}_T^{\,3} - 0.0599\bar{k}_T^{\,2} + 0.1504\bar{k}_T + 0.0754 \qquad \begin{cases} 0.3 \le \bar{k}_T \le 0.8 \\ \omega_s \le 81.4^\circ \end{cases}$$

The accuracy of the correlations was assessed by means of two widely used statistics: Root Mean Square Error (RMSE) and Mean Bias Error (MBE). The following expression for RMSE and MBE as a percentage of the average value were used:

$$RMSE = \frac{100}{\bar{D}}\sqrt{\frac{\sum_{i=1}^{N}(D_{ie}-D_{im})^2}{N}}$$

$$MBE = \frac{100}{\bar{D}}\frac{\sum_{i=1}^{N}(D_{ie}-D_{im})}{N}$$

Where N is the number of data, D_{ie} is the ith estimation value, D_{im} is the measured value and $\bar{D}$ is the mean of the measured values.
The results of these two equations which are derived for calculation of the solar radiation in khorasan province are approximately equal to the results of the Erbs et Al equations.

month	RMSE(%)	MBE(%)
Jan	3,43	0,12
Feb	7,89	0,62
Mar	4,63	0,21
Apr	2,01	0,04
May	1,56	0,02
Jun	2,43	0,06
Jul	0,85	0,01
Aug	3,68	0,14
Sep	3,68	0,14
Oct	5,36	0,29
Nov	0,9	0,01
Dec	8,81	0,78

Table (2) Error results

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