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COMPARISON OF DIFFUSE SOLAR RADIATION MODELS USING DATA FOR ONNE, NIGERIA

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ABSTRACT

Measurements of global solar radiation and sunshine duration data during the period from 1984 to 1999 were supplied by IITA (International Institute of Tropical Agriculture) at Onne The data were used to establish empirical relationships that would connect the daily monthly average diffuse irradiation with both relative sunshine duration and clearness index separately and in combination. The estimated results were then compared with measured values of a nearby location since measured data on diffuse radiation for this location is not available The correlation connecting diffuse radiation with percentage possible sunshine is found to be applicable over Onne

KEYWORDS: Diffuse, solar radiation, Onne.

INTRODUCTION

Data on global and diffuse solar radiation at any location is useful in the design of various solar energy utilization devices that may be applicable at such location. While global radiation measurements on a horizontal surface are now fairly common, diffuse radiation is only measured at a few locations due to the cost of the equipment required and the care needed for regular adjustment and calibration to allow for the seasonal progression of the path of the sun across the sky

In assessing the performance of systems utilizing solar energy the diffuse solar radiation on a horizontal surface at the ocation of interest is an important input parameter Diffuse irradiation also has an application in illumination inside buildings. It is only in recent years that some research stations (Nsukka, Ibadan, Zaria, Sokoto and Ilorin) in the country embarked on continuous monitoring of the diffuse solar radiation.

For stations where no measured data for diffuse solar radiation are available, the common practice is to estimate from measured parameters like global solar radiation and relative sunshine duration. This has been the method adopted by many researchers (Akpabio and Eno 2001; Al-Ayed et. Al 1989; Gopinathan, 1992 Gopinathan and Soler, 1994; Gopinathan, 1988; Gopinathan, 1988 Iqbal, 1979, Iqbal, 1979, Lewis, 1983; Page, 1961 Liu and Jordan 1960; Munear, 1997; Omar, 1994, Said et al 1989 and Trabea, 1999) The above-mentioned methods are convenient ways of deriving diffuse radiation on hourly, daily and monthly basis. In this work, we have used various correlation models to estimate diffuse solar radiation for Onne weather station

METHOD OF PREDICTION

The global solar radiation and sunshine duration during the period 1984 to 1999 were supplied by the IITA (International Institute of Tropical Agriculture) station at Onne, a high rainfall station located at latitude 4°46'N longitude 7°10'E with an altitude of 10m. Akpabio and Etuk, 2003 had used the same data to determine the relationship between global solar radiation and sunshine duration for Onne as shown in Table 1 below.

Prediction formulae

Three types of correlations are used in estimating horizontal diffuse solar radiation. The first type expresses monthly average daily diffuse solar radiation, H_d/H, as a function of the monthly average daily clearness index, $K_T = H/Ho$, where H_d, H and H_o are monthly average daily diffuse, global and extraterrestrial radiation on a horizontal surface. The second type expresses the fraction H_d/H_o as a function of the monthly average daily values of the bright sunshine hours, S, and the maximum possible sunshine hours, S^o. The last type of correlation expresses Hd/H as a function of both clearness index and percent possible sunshine. Examples of some well – accepted correlations that has been tested in other locations and found to predict diffuse radiation close to the measured values are as given below

Prediction of Diffuse Solar Irradiance

A description of the mathematical expression for the estimated correlations can be classified as follows

Type one correlation – this is the relation between diffuse solar radiation and clearness index as

$$H_d/H = 1.000 - 1.130K_T \quad (1)$$

$$H_d/H = 1.017 - 1.159K_T \quad (2)$$

$$H_d/H = 0.958 - 0.982K_T \quad (3)$$

$$H_d/H = 1.390 - 4.027K_T + 5.531K_T^2 - 3.018K_T^3 \quad (4)$$

Type two correlation – this is a relationship connecting diffuse solar radiation and sunshine duration as follows:

$$H_d/H = 0.791 - 0.635(S/S_o) \quad (5)$$

$$H_d/H = 0.697 - 0.577(S/S_o) \quad (6)$$

$$H_d/H = 0.754 - 0.654(S/S_o) \quad (7)$$

$$H_d/H = 0.163 - 0.478(S/S_o) - 0.655(S/S_o)^2 \quad (8)$$

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$$H_d/H = 1.135 - 2.126(S/S_o) + 1.717(S/S_o)^2 - 0.585(S/S_o)^3 \quad (9)$$

$$H_d/H = 0.143 - 0.368(S/S_o) - 0.434(S/S_o)^2 \quad (10)$$

Type three correlation – In addition to the above two types, a third type of correlation expressing diffuse solar radiation as a function of both clearness index and percent possible sunshine has the forms:

$$H_d/H = 0.879 - 0.575K_T - 0.323(S/S_o) \quad (11)$$

$$H_d/H = 1.194 - 0.838K_T - 0.446(S/S_o) \quad (12)$$

$$H_d/H = 0.927 - 0.164K_T - 0.595(S/S_o) \quad (13)$$

Page, (1961) developed Equation 1 for 10 widely spread sites between 40°N to 40°S latitude. Gopinathan developed Equations 2, 6, 9, 11 and 12 for six different locations in Southern Africa (Gopinathan, 1992; Gopinathan and Soler, 1994; Gopinathan, 1988 and Gopinathan, 1988) Iqbal, (1979a & b) developed Equations 3, 5 and 8 for the Canadian environment. While Equation 7, was developed by Lewis, (1983) for Zimbabwe. Liu and Jordan, (1960) developed Equation 4. Massaquoi, (1987) developed Equation 10, for predicting the diffuse solar radiation where only data on sunshine duration and measured global solar radiation are available. Akpabio and Eno, 2001 had employed the same equation 10 recently for estimating diffuse solar radiation for Uyo located at Latitude 5°02' N and Longitude 7°56'E. Finally; Trabea, 1999 developed Equation 13 for Egypt.

RESULTS AND DISCUSSION

The figure 1 below shows, a graph of the diffuse solar radiation for Onne using thirteen correlation models listed earlier. From the figure it is observed that, some of the correlations give extremely high values of diffuse solar radiation (example Gopinathan's correlation Equation 12). While other give too low values than is expected for such a location as Onne which is a high rainfall station (example Liu and Jordan correlation Equation 4). Again, from the figure we observe that correlation Equations 1, 2, 3, 4, 5, 6, 7, 11 and 12 present high values of the diffuse solar radiation for Onne during the months of February to June and September to October. This result does not agree very well with what is expected for this location, since naturally during February and October, the intensity of sunshine is usually great (Akpabio and Etuk, 2003). Hence, these correlations cannot be used to predict conveniently the diffuse solar radiation for Onne.

Correlation Equation 13 shows high values for diffuse solar radiation during February to June and September, though the value for September is comparatively lower than that for February to June. The high value for February disqualifies this correlation from being used to predict diffuse solar radiation for Onne. While correlation Equations 8 and 10 show high values for diffuse solar radiation between, the months of February to May and September to November. The result obtained using Gopinathan's correlation Equation 9 as presented in the figure gives high values of diffuse solar radiation from March to September during the rainy season when we have a great deal of water droplets in the atmosphere to scatter incident radiation from the the sun (Akpabio 1992). But during the dry season, October to February, the values are comparatively low. Thus, this correlation provides a good estimate of diffuse component of total solar radiation for Onne.

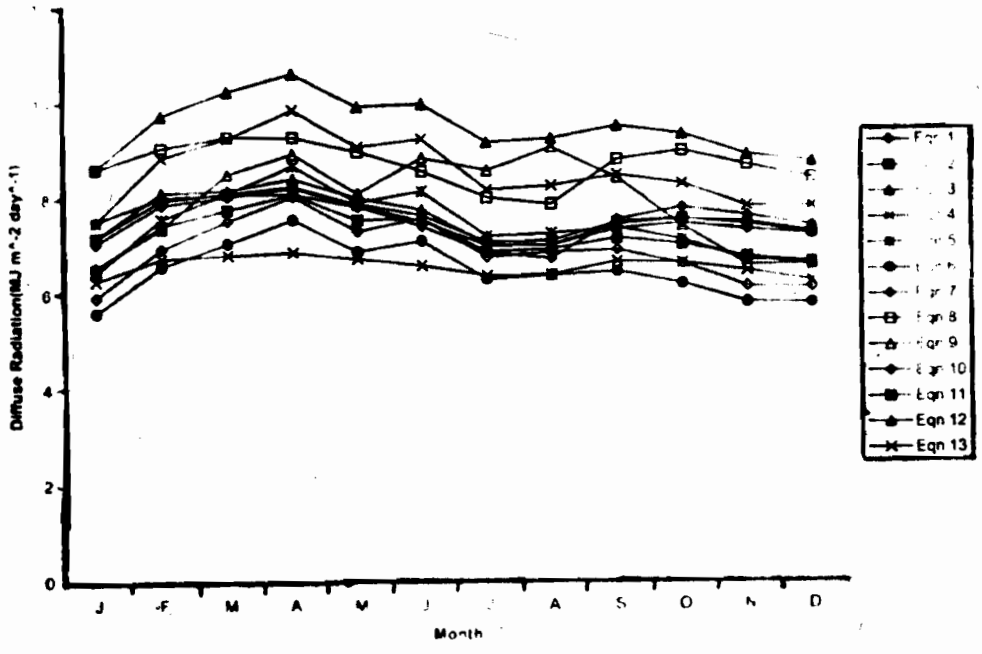

Fig. 1: Graph of diffuse solar radiation using thirteen correlation models

Table 1: Relevant meteorological and solar radiation data (H, Ho, S, So) for Onne (Akpabio and Etuk, 2003).

	Months											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
H	11.23	14.10	13.67	14.99	13.82	13.24	10.66	10.36	11.36	11.89	12.27	12.08
H_o	34.52	36.37	37.61	37.42	36.09	35.11	35.40	36.61	37.30	36.53	34.83	33.81
S	4.03	4.71	3.70	4.01	4.14	3.34	2.18	1.64	2.63	3.56	4.54	4.41
S_o	11.78	11.87	11.98	12.10	12.19	12.24	12.22	12.14	12.02	11.90	11.81	11.76

Generally, the diffuse ratios are high throughout the country (Nigeria) varying from 0.50 to 0.70 in the south (Nsukka and Ibadan) and 0.55 to 0.75 in the north (Zaria, Sokoto and Ilorin) as observed by Ezekwe, 1988. However, for Onne in the southern part of Nigeria, the diffuse ratio obtained from the correlation Equation 9 varies between 0.50 and 0.85. The peak ratio occurs in the July – August (with values of 0.81 and 0.88 respectively) months of the rainy season due to the sky being overcast with rain clouds. Ezekwe, 1988 had also observed the occurrence of peak ratio in the months of July – August for southern Nigeria. Since Onne has been declared as IITA high rainfall station (compared to other IITA stations such as Cotonu, Kano, Ibadan and Mbalmayo), the high values of diffuse ratio is what is expected for this station

CONCLUSION

The apparent scarcity of up-to-date diffuse solar radiation data makes it compelling to rely on correlation models for estimating and predicting the relevant monthly average values of diffuse fraction for the development of solar conversion systems. Thirteen models have been used to estimate the monthly average diffuse solar radiation on a horizontal surface at Onne. Due to the non-availability of measured data on diffuse solar radiation for Onne, the different correlations or models could not be tested for their validity or accuracy. Nevertheless, the result of Gopinathan correlation is better than that of the rest of the models used for estimating diffuse solar radiation for Onne when comparing the result of Ezekwe, (1988) for Nsukka

Therefore, it can be concluded that the simple correlation suggested by Gopinathan (Equation 9) is suitable and useful to predict the monthly average daily diffuse solar radiation for Onne location.

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