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Comparison of Measured Radiation Data with the Mathematically Estimated Solar Radiation Power for Hyderabad

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Abstract—*This paper presents the comparison of the mathematically estimated monthly average daily / hourly solar radiation to the measured solar radiation data for Hyderabad, India. Daily and hourly global radiation are estimated using mathematical correlation. Global radiations measurement are carried out using pyranometer. Angstrom correlation based estimates shows low variation from National Renewable Energy Laboratory data as well as measured global radiation data. Monthly average hourly global radiation are estimated by the Collares-Pereira- Rab correlation. Radiation estimation based on hourly measurement of insolation for the month of April shows that the strong influence of sky condition (cloudiness) on hourly radiation power profile. This method of estimation and comparisons can be used for establishing a solar radiation data for remote areas.*

Keywords: *Pyranometer, solar radiation, solar energy*

1. INTRODUCTION

Demand for solar energy as a viable alternative for conventional energy sources is increasing every year. Therefore the solar insolation data is of higher importance. For radiation power estimates, the insolation information data for a particular location (latitude and longitude) is essential. The solar radiation incident on a surface varies with time in a day and the intensity of radiation highly depend on the geographic location (latitude and longitude of the place), orientation and season time of day and atmospheric conditions. As it is known several years' insolation data is essential for a reliable estimate of solar power [1-3]. Most common radiation data are from pyranometer measurementsand satellite based measurement techniques[4] (NREL).Knowledge of monthly-mean values of the daily global and diffuse radiation on a horizontal surface is essential fordesigning any solar energy system. Therefore emphasis of this work on predicting the radiation from mathematical correlations as well as comparing it with actual measured data. Hourly values of radiation enable us to derive very precise information about the performance of solar energy systems. For locations where no measurements exist, monthly-mean values of the daily/hourly global and diffuse radiation on a horizontal surface are estimated by using empirical correlation developed from the measured data of nearby locations having similar climatological conditions. Mathematical model for estimating the global radiation was proposed by Angstrom [5], this was based on angle of incident and declination angle for different latitude and longitude. Several improvements were suggested by Gopinathan [6]K. K and KYang-GW Huang[13].As it has been widely seen in literature the coefficient for Angstrom correlation can be estimated by trigonometrically relations. Several attempts have been made to analyse the hourly global radiation. The method proposed by Collares-Pereira and Rabl [7] for hourly average radiation estimates was been found to be more appropriate.

Therefore present work is focused on radiation measurement using thermopile pyranometer and mathematical correlation based estimates.

2. METHODOLOGY

2.1 Mathematical relation for Radiation Data

Angstrom [5] developed the mathematical relation predicting the monthly average of the daily global radiation (Hg) as a function of the daily extra-terrestrial radiation on a horizontal surface (Ho) at a location and trigonometrical function of incident angles. The following relation is used to calculate monthly average daily global radiation

$$Hg= (a+b(S/Smax))*Ho$$

WhereS is the monthly average of the sunshine hours per day and $S_{max}$is the monthly average of the maximum possible sunshine hours per day at the location and is equal to $(2/15)w_s$, where w_s is the hour angle. a, b are the constants obtained for 17 Indian cities. For a particular place for which these constants are not available, a and b [8] can be calculated by these equations

$$a = -0.309 + 0.539 \cos\Phi - 0.0693\alpha + 0.290$$

b = 1.527 – 1.027 cosΦ +0.0926 α – 0.359

The constants a and b are related to three parameters, the latitude angle, the elevation angle

and the sunshine hours. The equation for Ho is given by

Ho=24Isc(1+.033cos(360n/365)((ωssinϕsinδ)+(cosΦcosδsinωs))

whereI_{sc} is the solar constant and is the rate at which energy is received from the sun on a unit area perpendicular to the rays of the sun, at the mean distance of the earth from the sun and its value is 1.367 kW/m^2. 'n' is the day in each month on which extra-terrestrial radiation nearly equal to the monthly mean value and for each month the value of n is different like 17 for January, 47 for February, 75 for March etc. and these dates represents the radiation incident of the particular month[9]

Φ is the latitude angle of the location

$\omega_s$is the hour angle corresponding to the sunshine or sunset on horizontal surface is given by equation

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

δ is the declination angle which is given by the equation δ = ±23.45 (Sin (360*(284+N)/365))

Fig. 1shows the variation of declination angle throughout the year.

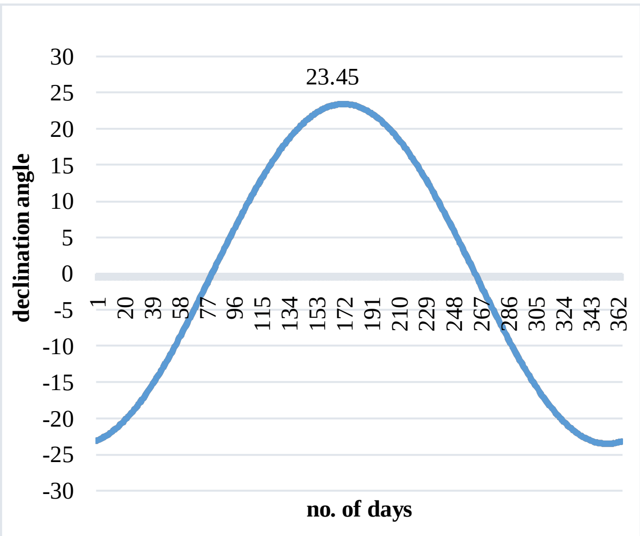

Fig. 1: Declination Angle throughout the Year for Hyderabad.

Garg and Garg [8] have examined radiation data for 11 Indian cities and proposed the equation for average daily diffuse radiation $H_{d\ as}$

*H_d= (.8677-.7365(S/Smax))*Hg*

Using the procedure described above, global (H_g) and diffuse radiation (H_d) were calculated for all the months of the year. The monthly average hourly global radiation at a location can be calculated by using the relation proposed by Collares-Pereira and Rabl [4]

*Ig=Io (a+bcosω)*Hg/Ho)*

Where a = 0.409 +0.5016 sin (w_s- 60^0) and

b = 0.6609 – 0.4767sin (w_s- 60^0)

I_g = monthly average of the hourly global radiation a horizontal surface (kW-h/m^2), I_0 = monthly average of the hourly extra-terrestrial radiation a horizontal surface (kW-h/m^2)).the equation for Io is given by

*Io=Isc(1+.033cos(360n/365)[(sinΦ*sinδ)+(cosΦ*cosδ*cosω)]*

The monthly average hourly diffuse radiation at a location is given by Liu and Jordan [11] are as follows *Id=Io*Hd/Ho.*

2.2. Radiation Measurement

The daily global solar radiation is to be carried out with the pyranometer which is the Secondary Standard (ISO 9060). Pyranometer data is stored in a data logger for easy measurement. Comparison of different methods for measuring solar irradiation data has been discussed in detailed by N. Gender [12]. Direct normal radiation can be estimated by data logger using global horizontal irradiance data and the actual sun height angle by known time and coordinates of the location. Measurements are taken at an interval of one hour starts from morning 9AM to evening 5PM.

Fig. 2: Pyranometer.

3. RESULTS AND DISCUSSION

3.1 Monthly average daily radiation

The monthly average daily global radiation value are mathematically estimated which is given in column 3 of table 1.For comparison the corresponding data from NREL [10] are given in column 2,as we can see with a minimum variation of 5% and a maximum of 20 % which is in the month of august. This may be due to more monsoon and climatic effect. On other seasons this variations are less. Monthly average data are estimated for several months, however sufficient data are available for estimating monthly average only for six months which is tabulated in column 4.The effect of climate can be seen in this data also.

Table 1: Estimated ,Measured and NREL data Global Daily Radiation in KWh/m^2/Day.

Month	NREL[10] Radiation data in Kwh/m^2/day	Calculated Daily Radiation in Kwh/m^2/day	Measured Daily Radiation in Kwh/m2/day
January	5.06	5.2	NA
February	5.82	5.91	5.1
March	6.36	6.64	6.1
April	6.51	6.94	6.4
May	6.28	6.29	NA
June	4.84	5.48	4.6
July	4.26	5.41	4.3
August	4.18	5.22	4.2
September	4.52	5.07	NA
October	4.79	4.91	NA
November	4.85	4.89	NA
December	4.74	5.1	NA

*NA- Data Not Available

NREL [10] data which is satellite based measurement incooperates the effect of actual climatic condition. This data represents large area around the specific location when compared to pyranometer data which represents radiation incident on measured location only. However these dataare more accurate values of the radiation when compared to mathematical estimate as it include the actual climatic conditions.

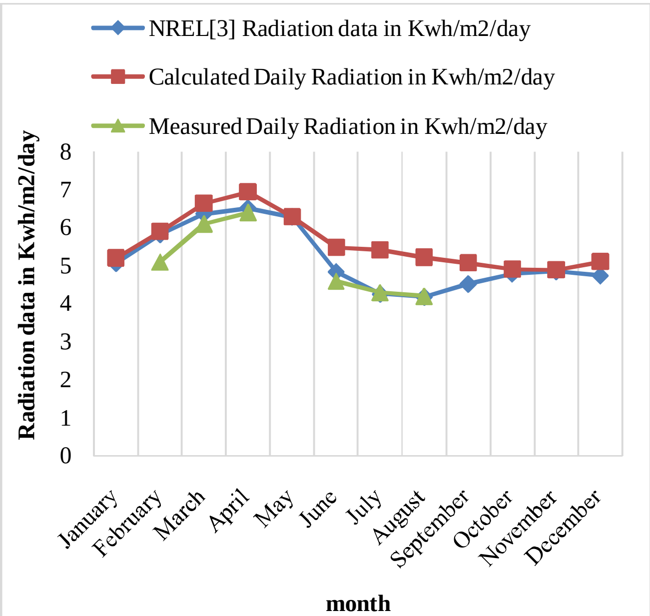

Fig. 3: NREL, Estimated and Measured Daily Global Radiation.

3.2 Monthly average hourly radiation

Collares-Pereira and Rabl [7] correlations are used for estimating hourly global radiation. Representives average radiation falls dates of the month are chosen to be 15 January, 16 February, and 16 March etc. The hourly radiations areestimated for at an interval of one hour from 9:00 to 17:00 hours IST which are shown in Fig. 4.

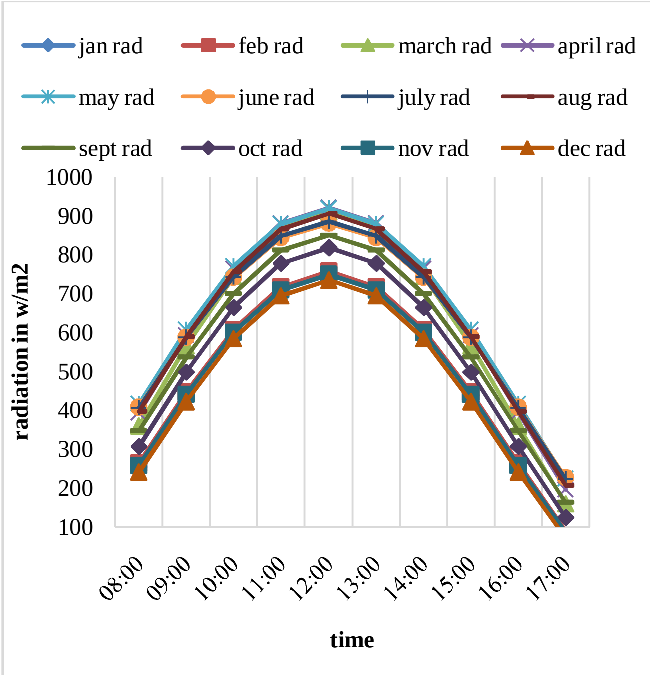

Fig. 4: Hourly Average Global Radiation for Every Month.

As shown in Fig. month of May is expected to give maximum hourly radiation and the value reaches up to 918.76 W/m^2 at the peak time 12:00 noon followed by the month June and July. The minimum hourly average global radiation of Hyderabad is found to be in the month of December followed by November.

Further in order to understand the variation within a month, the data from month of April is analysed. Four sets of data corresponds to 4th, 11th, 18th and 24th are mathematically estimated which are shown in table 2.

Table 2: Calculated Global Radiation for April.

Time	Rad* (W/m2) on 4th April	Rad* (W/m2) on 11th April	Rad* (W/m2) on 18th April	Rad* (W/m2) on 24th April
9	623.45	646.88	687.77	710.56
10	668.45	710.78	740.68	785.78
11	720.45	774.56	810.78	846.56
12	814.56	810.57	859.78	908.4
13	720.45	774.56	810.78	846.56
14	668.45	710.78	740.68	785.78
15	623.45	646.88	687.77	710.56

16	580.88	604.96	638.56	681.68
17	524.67	579.56	610.53	638.44

*Rad- Global Radiation

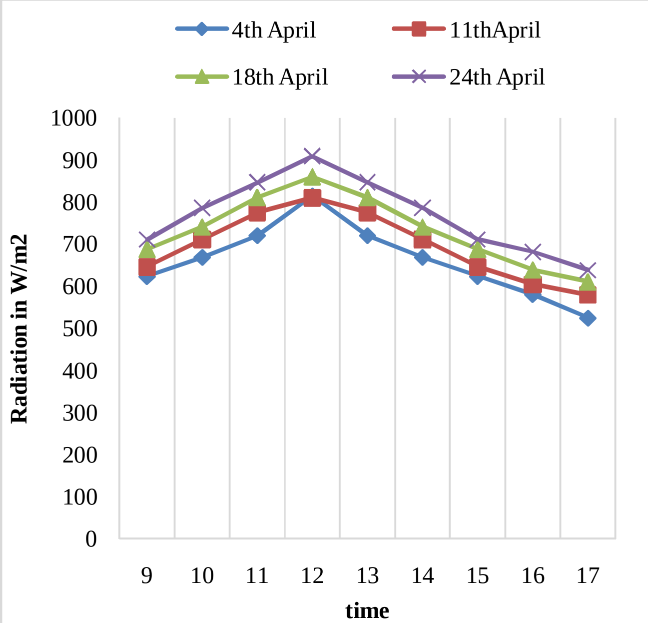

Fig. 5: Calculated Hourly Radiation for April Month.

The data in Fig. 5 shown a continuous increase in hourly radiation from 4th to 24th April .This is due to the continuous reduction in declination angle within this period. The measured values for the selected four days of April are shown in table 3.

Table 3: Measured Hourly Radiation for April Month.

Time	Rad* (W/m2) on 4th April	Rad* (W/m2) on 11th April	Rad*(W/m2)on 18th April	Rad* (W/m2) on 24th April
9	547.46	524.67	543.86	598.58
10	568.24	579.46	556.57	658.21
11	610.48	630.56	617.46	785.35
12	675.62	721.54	796.88	864.46
13	673.35	693.28	758.82	810.18
14	613.57	660	688.46	752.73
15	573.26	624.58	642.42	689.58
16	560.46	540.67	566.85	630.56
17	524.67	490.34	510.34	580.24

*Rad - Global Radiation

Continuous increase in hourly radiation is expected in measured data also. However the measured data may not follow this trend exactly due to the climatic conditions of the day. As in case of 11th April sky condition found influencing the hourly global radiation at different period of a day.

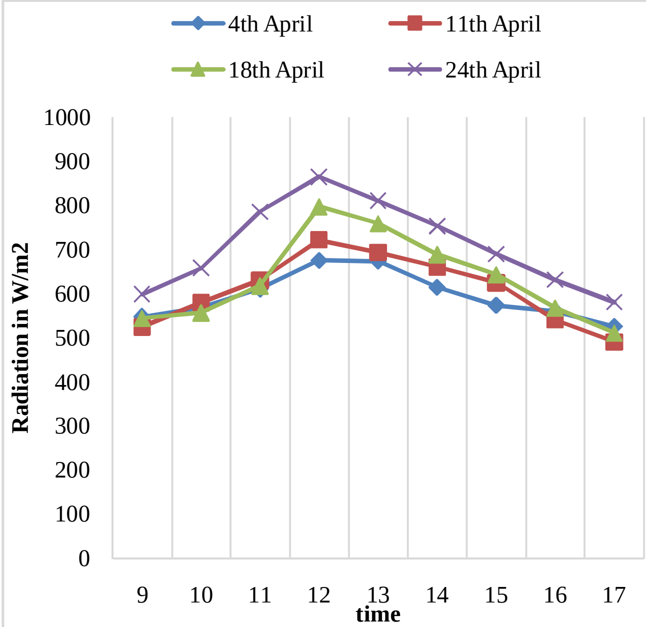

Fig. 6: Measured Hourly Radiation for April Month.

The hourly global radiation has been calculated by the method proposed by Collares-Pereira and Rabl [7]. The measured data for monthly hourly global radiation is available for six months which are used to compare with the mathematically estimated results. For the remaining months, sufficient measured data were not available for these estimations which is given as 'NA' in the table. Table 4 shows the calculated and measured hourly global radiation for every month at 12 noon in W/m^2.

Table 4:Calculated and Measured Hourly Global Radiation for Every Month at 12 Noon in W/m^2.

Month	Calculated hourly global Radiation in W/m2	Measured hourly global Radiation in W/m2
January	754.02	NA*
February	756.7	734.86
March	910.43	880.32
April	921.36	868
May	918.76	NA
June	880.45	870.62
July	885.48	840.44
August	906.57	754.88
September	850.66	NA
October	818.23	NA
November	749.27	NA
December	734.56	NA

*NA – Not Available

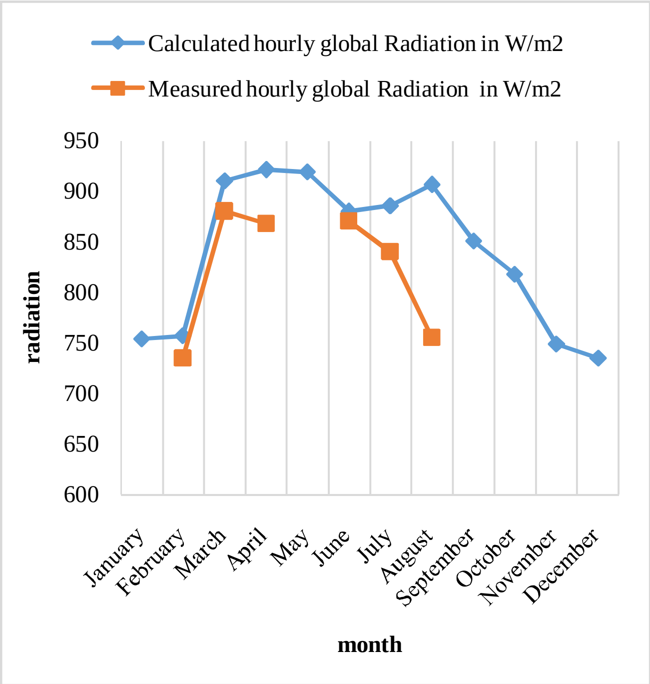

Fig. 7: Calculated and Measured Global Radiation at 12 Noon for Every Month.

Fig. 7 suggest that there is a variation between the calculated and measured results for monthly average hourly global radiation. These variationslies withina range of 6% to the 17%.The minimum variation is in the month of June and maximum in the month of august due to the effect of sunshine hours and the cloudiness throughout the average days of month.

4. CONCLUSION

The radiation data for Hyderabad has been estimated by using mathematical correlations .Radiations are measured for same period. Mathematically estimated data is found to be in good agreement with measured data for the time periods where the climatic condition permits good sunshine. This study shows the comparison of measured and the estimated values can result in generating reliable radiation data for different location.

REFERENCES

[1] *Journal of Engineering Science and Technology Review 5 (2) (2012) 12-19*Estimation of global solar radiation using clear sky radiation in Yemen M. Maroof Khan.

[2] Page JK. The estimation of monthly mean values of daily total short wave radiation on vertical and inclined surfaces fromsunshine records for latitudes 40 N-- 40 S. Proc of UN Conf onNew Sources of Energy 1964;4:378.

[3] Energy 30 (2005) 1517–1531solar radiation modelling and measurements for renewable energy applications: data and model qualityDaryl R. Myers.

[4] C. Schillings, R. Meyer, H. Mannstein, "*Satellite-derived high resolution solar direct normal irradiance*, Part I: Method, Part II: Results and Validation", (submitted to Solar Energy Nov. 2002)

[5] Angstrom A. (1961) *Techniques of determining the turbidity* ¨ of the atmosphere. Tellus 13, 214–223.

[6] Modi, Vijay and Sukhatme S.P (1979) *Estimation of daily and total insolation in India from weather data, Solar energy, 22, 407*Gopinathan (write from Sukhatme)

[7] Collares-Pereira, M, Rabl (1979), the average distribution of solar radiation— *correlation between diffuse and hemispherical and between daily and hourly insolation values*, Solar Energy, 22 155.

[8] Garg H. P. and Garg S. N. (1985), *Correlation of monthly-average daily global diffuse and beam radiation with bright sunshine hours*, Energy Conversion and Management, 25, 409

[9] India Solar Resource Maps (2010): http://*www.mnre.gov.in/centers/about-sec-2/solar-resources/*, Ministry of New and Renewable Energy Govt. of India

[10] *https://eosweb.larc.nasa.gov/cgibin/sse/retscreen.cgi?email=rets%40nrcan.gc.ca&step=1&lat=17.36&lon=78.46&submit=Submit.*

[11] Liu, B. Y. H. (1960), the interrelationship and characteristic distribution of direct, diffuse and total solar radiation, Solar Energy, 4, 1.

[12] *3rd International Conference on Experiences with Automatic Weather Stations, 19th-21st of February 2003, Torremolinos, Spain* Comparison of Different Methods For Measuring solar irradiation data by N.Geuder.

[13] Solar Radiation. †. K. YANG , G. W. HUANG and N. TAMA A hybrid model for estimating global solar radiation.