# Solar power Estimate Using Different Empirical Constant

M.Kesavan [1] and M.Senthil Kumar [2]

[1]*Assistant Professor, Department of Mechanical Engineering, Annamalai University, (Deputed to GPTC Aranthnagi), Annamalai nagar,Tamilnadu, India.*

[2]*Assistant Professor,Department of Mechanical Engineering, Annamalai University, (Deputed to GPTC Dharmapuri), Annamalai nagar,Tamilnadu, India.*

**ABSTRACT**

*Solar radiation data an important role in solar energy. Theses radiation data are not available for all location of interest due to absence of meteorological station, especially in remote locations. This study evaluates different empirical models on Angstrom Present model to estimate global solar radiation using specific connection based on sunshine hours. We have estimated the value of monthly global solar radiation for Chennai. The values of monthly average global solar radiation are calculated using the expression constants in the models.(linear, quadratic, cubic, log, exponent) all the regression models investigated, validated and compared. The calculated data from these models is compared with the data provided by MNRE. The calculated and measured data are simulated using MAT-LAB, on comparison. It was observed that the cubic models are overall more accurate for calculating the global solar radiation for the Chennai region. The regression co-efficient is used to find the curve fitting technique. The present works will help to advance the state of knowledge of global solar radiation to the estimation of solar global radiation (SGR).*

***Key Words***: *curve fitting tool, Daily global solar radiation, Empirical models, Sunshine hours, Validation, MAT-LAB.*

## 1 INTRODUCTION

The earth and its atmosphere depend ultimately on the sun for its energy supply. The radiant energy from the sun covers the entire electromagnetic spectrum. The atmospheric interference restricts this spectrum to 290nm to 300nm which is called “Solar radiation” energy. From solar radiation can be derived by thermal conversion where in the heat generated due to irradiation is used to operate a system and by direct conversion into electrical energy. The accurate information of the solar radiation intensity at a given location is essential to the development of solar energy based projects and in the long term evaluation of the solar energy conversion systems performance [1]. This information is used in the design of a project. Furthermore monthly mean daily data are needed for the estimation of long term solar systems performances. Furthermore daily global solar radiation models required for engineering design and planning projects [2,3]. Solar radiation which arrives to earth surface for every year is 160 times the world’s proven fossil fuel and reserves [4]. A global study has been made on the global solar radiation models are available the study carried out an estimation of the monthly average daily global solar radiation on horizontal surface [5] among several empirical models which have been used to calculate global solar radiation the most commonly used parameters in sunshine hours [6].The empirical models has been used to calculate global solar radiation are usually based on some factors as shown in table (1)[7]. Since the solar radiation reading the earth’s surface depends upon climate condition of the place. A study of solar radiation under local climatic conditions of the place is necessary. This knowledge of local solar radiation is essential for the proper design of buildings energy systems, solar energy systems and a good evaluation of thermal environment within the buildings [8-11]. It is measured in terms of sunshine duration. One way of solving this is using appropriate correlations which are empirically established that can be used to estimate global solar radiation from more readily available metrological parameters such as sunshine hours. Several empirical models have been developed to calculate solar radiation from meteorological, geographical, climatologically parameters such as relative humidity, ambient temperature, soil temperature, number of rainy days and evaporation [12-18]. In addition, other empirical models have been developed to calculate solar radiation from sunshine hours [19-22]. The most commonly used parameters for estimating global solar radiation are sunshine duration among various correlations. The modified variations of [23] model who proposed a linear relationship between the ratio of corresponding value on a clear sky day and the ratio of average daily sunshine duration to the maximum possible sunshine duration and its derivatives have been widely used. Empirical models which have been used to calculate global radiation are usually on some factors as shown in table [1], [23]. The Solar radiation data computed based on measured metrological data computed data. The average daily global radiation on horizontal surface it, for a location is now possible of sunshine hours five different models have been selected from different previous studies for estimating daily global solar radiation. All models have been proposed for estimating for monthly mean daily global solar radiation, H-based on the Angstrom-Prescott model [24].

**TABLE 1: CLASSIFICATION OF PARAMETERS USED TO CALCULATE SOLAR RADIATION (GSR)**

| Classification | Parameter |
|---|---|
| Meteorological factors | Extraterrestrial solar radiation, sunshine duration, temperature, precipitation, relative humidity, effects of cloudiness, soil temperature, evaporation, reflection of the |
| Geometrical factors | Azimuth angle of the surface, tilt angle of the surface, sun elevation angle, sun azimuth angle. |
| Physical factors | Scattering of dust and other atmospheric constituents such as $O_2$, $N_2$, $Co_2$ and O |
| Geographical factors | Latitude, Longitude and elevation of the site |
| Astronomical factors | Solar constant, earth – sun distance, declination and hour angle |

## 2 NEEDED FOR SOLAR RADIATION DATA

A whole array of application via, thermal conversion, photovoltaic conversion, photochemical utilization, biomass of buildings, detoxication etc is becoming apparently viable and enhances the societies energy management planning and hence its efficient applications. The economics of these technologies depend on the efficiency of the utilizing processes. So that the operating costs are comparable if not cheaper. With the present day processes based on conventional fossilized energy utilization. Thus to design operating systems which will have the highest achievable efficiency under comparable costs. The reliable database on different aspects of solar radiation energy is essential. The more accurately the solar resources are known. The better becomes the system design the radiation energy available at a location changes throughout the day and year due to varying weather patterns by knowing the variability storage systems can be designed and used optimally. Solar radiation data also help to determine the best geographic location for utilization as it will have a direct influence on the design of the systems. Photovoltaic and photochemical conversions need spectral distribution over space and time, location, climate and atmospheric conditions have strong influence on the spectral distribution of solar irradiance.

**TABLE 2: THE REGRESSION MODELS PROPOSED IN LITERATURE**

| Model No | Regression Equation | Model Type |
|---|---|---|
| 1 | $H/H_o = a+b\,(s/S_o)$ | Linear |
| 2 | $H/H_o = a+b\,(s/S_o)+c(s/S_o)^2$ | Quadratic |
| 3 | $H/H_o = a+b\,(s/S_o)+c(s/S_o)^2+d(s/S_o)^3$ | Cubic |
| 4 | $H/H_o = a+b\log(s/S_o$ | Logarithmic |
| 5 | $H/H_o = a+b\exp(s/S_o)$ | Exponential |

## 3 CALCULATION PROCEDURES

Many different models have been found in the literature such as linear, quadratic, cubic, logarithmic, exponential regressing model to estimate on a horizontal surface from observed sunshine duration and calculate extraterrestrial radiation and maximum possible sunshine duration. In this study model have been investigated and validity of this model has been made. The Angstrom Prescott model [24] that examines the linear correlation between clearness index ($H/H_0$) and sunshine duration ratio ($S/S_0$) is most commonly used model. The equation used in this model is,

$$H/H_0 = a + b\,(S/S_0) \qquad (1)$$

Where H is monthly average daily global radiation on a horizontal surface,

$H_0$ is a extraterrestrial radiation on a horizontal surface

S is a monthly average daily sunshine duration

$S_0$ is a monthly average maximum possible daily sunshine duration and

a, b are Angstrom coefficient (also called regression coefficient)

$$H/H_0 = a + b\,(S/S_0) + C\,(S/S_0)^2 \qquad (2)$$

The quadratic model is proposed by Akinolgu and Ecevit .et.al [25] and the related equation isThe cubic model is proposed by Bahel et .al [26]. And the related equation is

$$H/H_0 = a + b\,(S/S_0) + C\,(S/S_0)^2 + d\,(S/S_0)^3 \qquad (3)$$

The logarithmic model is proposed by D.B Ampratoumandet.al [27] and the related equations is

$$H/H0 = a + b\log(S/S0) \qquad (4)$$

The exponential model is proposed by J. Almorexet.al [28] and related equation is

$$H/H_0 = a + b\exp(S/S_0) \qquad (5)$$

The monthly average daily extraterrestrial radiation on a horizontal surface can be calculated by following equation [29]

$$H0 = 24*3600/\pi * I\,sc * (1 + 0.003\cos 360*n + (284+d/365))\,(\cos Ø\ \cos \delta\ \sin w_s \sin \pi(\sin w_s/180)) \qquad (6)$$

Where Ic is the solar constant (1367 W/m2), Ø is the latitude of the location , s is the sun declination and Ws is the sunset hour angel for a given month and D or N is the no of days of the year starting from 1st of January. Declination sunset hour angel and day length can be computed by the following equation [30, 31].

$$s = 23.45 \sin [360 + (284+(d/365)]\quad (7)$$

Where d is the day of the year 365 $1 \leq d \leq 365$

$$W_S = \cos^{-1} (- \tan Ø \tan s)\quad (8)$$

$$S_0 = 2/15\ w_S\quad (9)$$

Further five different models have been selected from different previous studies for estimating daily global solar radiation. All models having proposed for estimating the monthly mean daily global radiation. H based on the Angstrom Prescott model, extraterrestrial radiation on a horizontal surface sin daily period where calculated numerically for each month using declination angel, latitude and sunset hour angel from the calculation procedure using the equation [32, 33, 34]. Then we develop equation to estimate $H/H_0$ for each month by applying regression analyze to the parameter $S/S_0$ based on the model equation, five model equation for each month where formed. The values of monthly average of daily solar radiation estimated for each month. The corresponding measured value are compared with the estimated values using the above five models for each month.

### 3.1 STATISTICAL ROUTINE

Each month was evaluated on the basis of the statistical error tests, (i.e. the mean bias error (MBE), mean percentage error (MPE), root mean square error (RMSE), and coefficient of determination, $R^2$.The equations were also tested whether they are statistically significant using *t*- statistics.

#### 3.1.1 THE MEAN BIAS ERROR

$$MBE = \frac{1}{N}\sum_{i=1}^{N}(Ci - Mi)\quad (10)$$

where Ciand Miare the forecast and actual values of solar radiation being forecast respectively, and N is the number of observations. This test provides information on long- term performance. A low MBE value is desired. A mean error value of zero can mean the method forecasts the actual values perfectly or that the positive and negative errors cancel each other out. So, one drawback of this test is that it tends to understate the error in all cases.

#### 3.1.2 MEAN PERCENTAGE ERROR

$$MPE(\%) = \frac{100}{N}\sum_{i=1}^{N}\frac{Ci - Mi}{Mi}\quad (11)$$

MPE quantifies the schematic component of the normalized difference for individual observations. It is subjected to the averaging of the positive and negative errors. A percentage error between −10% and +10% is considered acceptable.

#### 3.1.3 THE ROOT MEAN SQUARE ERROR

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}(Ci - Mi)^2\ \frac{1}{2}\right]\quad (12)$$

The value of RMSE is always positive, representing zero in the ideal case. The normalized roots mean performance of the correlations by allowing a term by term comparison of the actual deviation between the predicted and measured values. The smaller the value, the better is the model's performance.

### 3.1.4 THE COEFFICIENT OF DETERMINATION, $R^2$

The coefficient of determination, *R give some* information about the goodness of fit of a model.Inregression, the $R^2$ coefficient of determination is a statistical measure of how well the regression line approximates the real data points.

3. $t = \frac{(N-1)(MBE)2}{(RMSE)2-(MBE)2}$ $)^2$ - $(MBE)^2$ (12)

T-statistics is an indicator of adjustment between calculated and measured data allowing the data to be compared. It can be used to induce whether or not data measurements are statistically significant at a particular confidence level.

## 4 RESULTS AND DISCUSSION

The accuracy of five model equations were determined using data measured at Chennai city from. The regression coefficients *a, b, c* and *d* are given for all five models for each month are shown in Tables 4.1.

### TABLE 4.1: REGRESSION COEFFICIENT FOR CHENNAI CITY

| Model Type | Model Number | A | b | c | d |
|---|---|---|---|---|---|
| linear | 1 | 0.059 | 0.631 | - | - |
| log | 2 | 0.681 | 0.503 | - | - |
| Power | 3 | 0.689 | 0.893 | - | - |
| Quadratic | 4 | 0.112 | 0.497 | 0.083 | - |
| $t = \frac{(N-1)(MBE)2}{(RMSE)2-(MBE)2}$ | | 1.193 | -3.642 | 5.326 | -2.196 |

The regression coefficients were obtained using curve fitting tool in MATLAB. The values of the mean daily global solar radiation estimated using the above five models were compared with the corresponding measured values. Statistical test MBE, MPE, RMSE, R and *t*-test were determined for all five model equations for each month of the year. The applicability of the proposed correlations in predicting the daily mean global solar radiation is tested by estimating values for C h e n n a i c i t y used in the analysis. Estimated values for the five models with measured data for the months January to December shown in Tables 4.2.

**TABLE 4.2: COMPARISON BETWEEN MEASURED AND ESTIMATED VALUES (H) OF THE CORRELATION EQUATION (CHENNAI CITY)**

| Statistical parameters | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| MBE | -0.0007 | 0.0002 | 0.0001 | 0.0001 | 0.0000 |
| MPE | -0.1189 | 0.0383 | 0.0171 | 0.0179 | 0.0074 |
| RMSE | 0.0024 | 0.0015 | 0.0013 | 0.0014 | 0.0014 |
| $R^2$ | 0.9956 | 0.9910 | 0.9956 | 0.9956 | 0.9966 |
| t-stat | 0.9574 | 0.9574 | 0.9574 | 0.9574 | 0.9576 |

odel 5

It was found tl ... 16% to zero
for January, -0 ... o have very
low RMSE va ... o 0.002 for
November. Al ... t-test were
always equal t ... etween the
different mod ... e critical t
values.These r ... e also high
(above 0.95) ... with the
measured data. ... indicators
for predicting ... d for use to
estimate the d ... titude and
altitude as ... global solar
radiation usin ... November
respectively.

**TABLE 4.2:**
**(CHENNAI)**

| | |
|---|---|
| Jan | 1 |
| Feb | 2 |
| Mar | 2 |
| Apr | 2 |
| May | 2 |
| Jun | 2 |
| Jul | 1 |
| Aug | 1 |
| Sep | 2 |
| Oct | 1 |
| Nov | 1 |
| Dec | 1 |

| | (MJ/m²) | (MJ/m²) | (MJ/m²) | (MJ/m²) | (MJ/m²) | (MJ/m²) |
|---|---|---|---|---|---|---|
| Jan | 17.56 | 17.39 | 17.81 | 17.68 | 17.65 | 17.65 |
| Feb | 21.06 | 20.39 | 20.75 | 20.70 | 20.70 | 20.72 |
| Mar | 23.46 | 23.32 | 23.56 | 23.63 | 23.68 | 23.60 |
| Apr | 24.13 | 23.85 | 24.18 | 24.19 | 24.21 | 24.19 |
| May | 22.86 | 22.33 | 22.82 | 22.68 | 22.66 | 22.69 |
| Jun | 21.41 | 21.19 | 21.71 | 21.54 | 21.51 | 21.50 |
| Jul | 19.62 | 19.65 | 20.12 | 19.99 | 19.97 | 19.90 |
| Aug | 19.05 | 18.55 | 18.90 | 18.89 | 18.90 | 18.85 |
| Sep | 20.07 | 19.64 | 20.13 | 19.98 | 19.95 | 19.90 |
| Oct | 17.41 | 17.12 | 17.48 | 17.42 | 17.43 | 17.36 |
| Nov | 14.61 | 14.43 | 14.55 | 14.69 | 14.75 | 14.80 |
| Dec | 14.69 | 14.64 | 14.93 | 14.90 | 14.91 | 14.86 |


| Month | Measured (MJ/m²) | Model 1 (MJ/m²) | Model 2 (MJ/m²) | Model 3 (MJ/m²) | Model 4 (MJ/m²) | Model 5 (MJ/m²) |
|---|---|---|---|---|---|---|
| Jan | 17.56 | 17.39 | 17.81 | 17.68 | 17.65 | 17.65 |
| Feb | 21.06 | 20.39 | 20.75 | 20.70 | 20.70 | 20.72 |
| Mar | 23.46 | 23.32 | 23.56 | 23.63 | 23.68 | 23.60 |
| Apr | 24.13 | 23.85 | 24.18 | 24.19 | 24.21 | 24.19 |
| May | 22.86 | 22.33 | 22.82 | 22.68 | 22.66 | 22.69 |
| Jun | 21.41 | 21.19 | 21.71 | 21.54 | 21.51 | 21.50 |
| Jul | 19.62 | 19.65 | 20.12 | 19.99 | 19.97 | 19.90 |
| Aug | 19.05 | 18.55 | 18.90 | 18.89 | 18.90 | 18.85 |
| Sep | 20.07 | 19.64 | 20.13 | 19.98 | 19.95 | 19.90 |
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| Jan | 17.56 | 17.39 | 17.81 | 17.68 | 17.65 | 17.65 |
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| Mar | 23.46 | | | | | |
| Apr | 24.13 | | | | | |
| May | 22.86 | | | | | |
| Jun | 21.41 | | | | | |
| Jul | 19.62 | | | | | |
| Aug | 19.05 | | | | | |
| Sep | 20.07 | | | | | |
| Oct | 17.41 | 17.12 | 17.48 | 17.42 | 17.43 | 17.36 |
| Nov | 14.61 | 14.43 | 14.55 | 14.69 | 14.75 | 14.80 |
| Dec | 14.69 | 14.64 | 14.93 | 14.90 | 14.91 | 14.86 |

[2


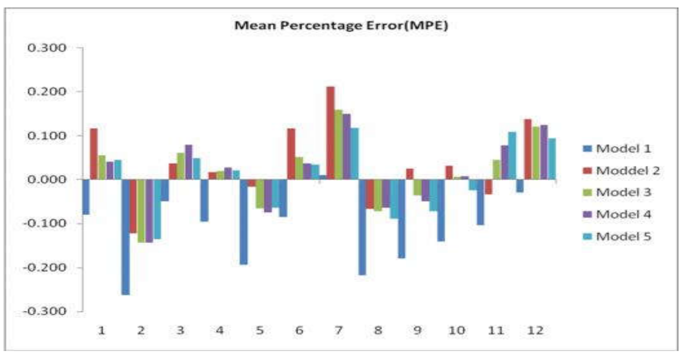


Fig. 4.2 Month Vs Mean Vias Error

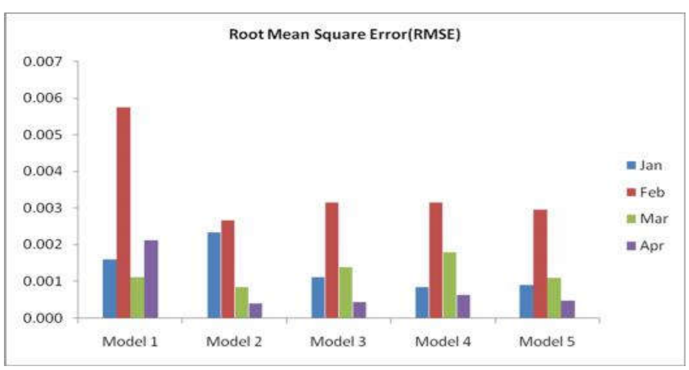


Fig 4.3. Model Vs Root Mean Square Error

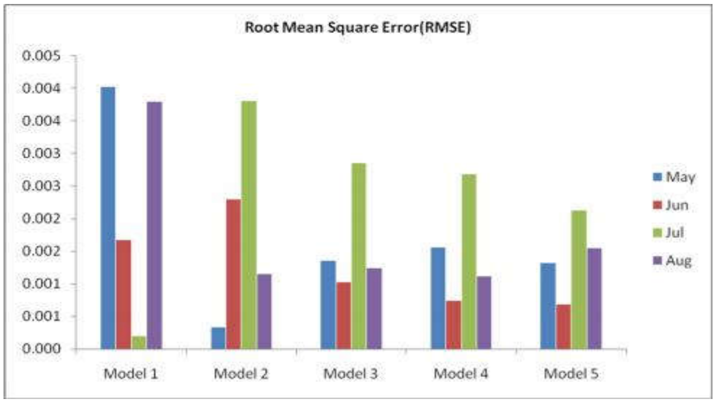


Fig. 4.4 Model Vs Month

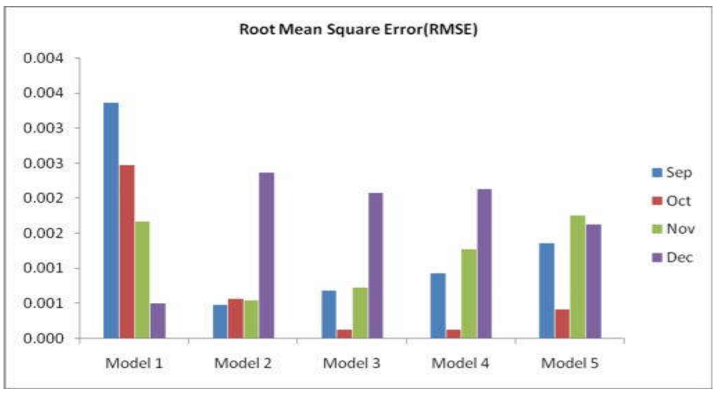


Fig 4.5. Model Vs Root Mean Square Error

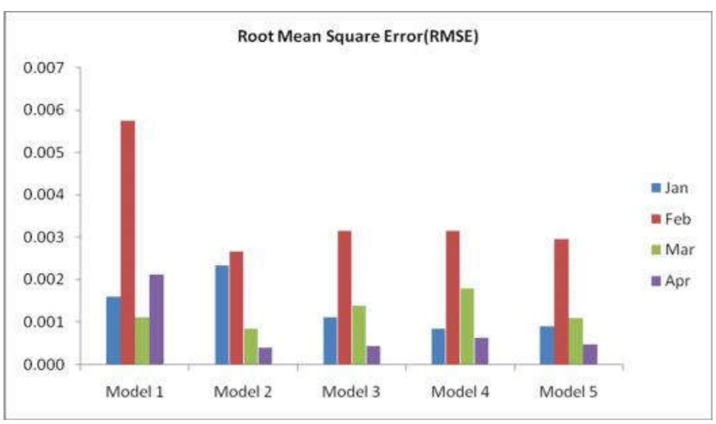


Fig 4.6. Model Vs Root Mean Square Error

## V CONCLUSIONS

The main objective of this paper is to calculate the global solar radiation from sunshine duration. The calculated results are compared with the measured data available at Chennai, and calculated value found to be acceptable within the limited error range.

- Based on the radiation data and sunshine hours data were provided by IMD.
- The linear, quadratic, cubic, logarithmic and power equations are generated and also investigation on regression models.
- According to the statistical test results are obtained and graphs were plotted the cubic models are accurate than the other regression models.
- These regression models give good agreement between the measured and computed values of solar global radiation. Although all five developed models are able to found good accuracy the correlation of solar radiation and sunshine data. (Cubic) gives the more accuracy fit for the Chennai region
- The percentage of error between measured and calculated results for Chennai region lies within the range of 10% to 15% models can be used for the validation of local solar radiation data, which is essential for the design of infrastructure, solar power plants etc.., for the developing country.

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