# Development of simulation weather data for Hour wise Daily Diffused and Direct Solar Radiation from Hourly Global Radiation using statistical estimation method for Subtropical region

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**Abstract-** In order to carry out energy simulation using software, a weather file containing various hour wise daily weather parameters including solar global, diffused and direct radiations is needed. These parameters shall be averaged either for a minimum of the past 10 year or for three characteristic years, namely, typical, coldest and hottest from the past 10 year period and the latter approach is used in this paper. The hourly modelled data for study location was available with National Renewable Energy Laboratory for 2003-11, whereas latest data from September 2011 onwards, except for diffuse and direct radiations, was available with Centre of Energy and Environmental Engineering, NIT Hamirpur. It is realized that this latest data must also be included to obtain a weather file. A yearly data of the desired radiation components were measured at the same Centre using SOLYS 2 Sun Tracker and the relationship of diffuse and global components is established using clearness index. This paper outlines three developed hourly regression models for measured data classified as annual, seasonal and hour wise (6AM to 6PM). The developed models along with various available prediction models for hour wise analysis are evaluated for performance statistical test methods of mean bias error, root mean square error, Pearson's correlation coefficients and mean absolute percentage error and also compared with various prediction models for performance at 7AM, 11 AM, 1 PM and 6 PM. It is found that the hour wise model performs better and hence is recommended for determination of diffused and direct components of available data.

**Keywords** Hour wise, diffused solar radiations, global solar radiations, regression models, subtropical, Hamirpur.

## 1. Introduction

In 2001, the concerted effort for judicious use of energy came in India with the Energy Conservation Act [1]. The act resulted in launch of the Energy Conservation building code (ECBC) through the Bureau of Energy Efficiency (BEE) [2]. This code has both prescriptive as well as a whole building performance approach for which energy performance evaluation of the proposed building and its alternatives shall be done in compliance. Whole Building Performance Approach is a more flexible approach that provides scope for innovation in design and hence is preferred over prescriptive approach. However, this approach requires the use of energy simulation software for which availability of weather file is a prerequisite [3]. Similarly a native building rating system named Green Rating Integrated Habitat Assessment (GRIHA) [4] is adopted by the Ministry of New and Renewable Energy Sources (MNRE) in 2007 to promote green buildings in India. This rating system requires energy analysis and improvement of building for energy use using simulation software. Also the state government of Himachal Pradesh, wherein the study area of this paper is located, has recently modified their Town and Country Planning Rules [5] for inclusion of solar passive features in building design for which simulation can be used as an effective tool.

A simulation is an energy modelling method [6], which is a virtual environment to create reality. It is based on the real time information input of building's parameters and results in providing building energy use that can be compared with its alternatives. The simulation method has several advantages like reliability of results, cost effectiveness, time saving, easy evaluation of virtual alternate conditions [7-10] whereas have several disadvantages include unavailability of weather file, knowledge of simulation software, results variability in a number of software etc. [11]. However, considering the advantages, simulation is considered a suitable tool by designers to design energy efficient buildings especially as per energy regulations. It is a software program that uses algorithms for various predictions under given real-time conditions for which building characteristics, occupants' behavior and outdoor environment conditions shall be known. The first two conditions are case specific and can be estimated from the building under study, whereas outdoor environmental conditions are usually obtained from secondary data or from a reliable source that contains a number of parameters those are monitored hour wise for a particular location for one typical year period and compiled to make a weather file [12]. The most important parameters present in a weather file shall have hour wise daily (365 days x 24 hours= 8760) measured data entries for Dry bulb temperature, Dew point temperature, Rainfall, Humidity, Wind speed and Direction, Atmospheric pressure, Cloud cover, Global solar radiations, Diffused solar radiations and Direct solar radiations. The parameter's hourly data shall be obtained by averaging for a minimum of the last 10 years [13] and in no case shall be for any one year as one year conditions may not predict energy use during extreme climates and the calculations/ projections may not be accurate for the life cycle of the building [14]. However, as recommended by [15], the data of three characteristic years, namely typical, coldest and hottest from the past 10 year period can be averaged to develop such as a file, and this method is used in the paper.

## 2. Need of the problem

This paper is an outcome to eliminate one of the most common problems that designers face today, which is the availability of weather file. Usually information for most of weather file parameters are made available from various meteorological stations except for diffused and direct components of solar radiations. Hence a methodology is presented in this paper to generate hour wise daily data for diffuse and direct components from available hour wise global solar radiation data.

There are two sets of data available for this study. One set of data is the hourly modelled data for study location was available with National Renewable Energy Laboratory (NREL) for 2003-11 (9 years) (henceforth called modelled data), whereas another set of data available is the latest data between September 2011 – December 2014 in which all parameter's data except for diffuse and direct radiations was available with Centre of Energy and Environmental Engineering (CEEE), NIT Hamirpur (henceforth called available data). It is realized that this latest data must be included to obtain minimum 10 years data which is a prerequisite requirement for development of a weather file. The average ambient temperature was calculated from the above data and is presented in Fig. 1:

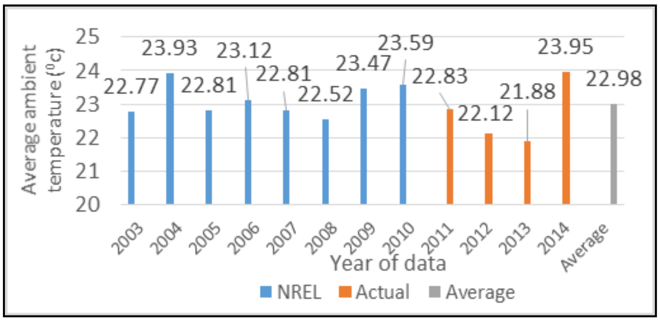



**Fig 1:** Average ambient temperature of year 2003-2014

It is found that the average year is 2011, whereas most cold year is 2013 and most hot year is 2014. Hence the data of these years can be utilized for development of weather file. The approach of using average data of the characteristic years is preferred over use of mixtures of NREL modelled and CEEE available data, as the desired three characteristic years data are available from one source (CEEE) thereby eliminating calibration and equipment errors. Also, this approach will avoid data inconsistency such as difference in measurement techniques and also eliminate the data accuracy error due to slight variations in coordinates of both sites.

With the use of this approach, the problem associated was to determine the diffuse and direct components of the available data, so that the desired weather file can be obtained.

## 3. Literature review:

Many studies are done by using a widely accepted index named clearness index ($M_T$), which is used to characterize the sky conditions for a location. The index is a ratio of the global solar radiation measured at the surface to the extra-terrestrial solar radiation. [16-32]. Studies generally calculate monthly average hourly diffuse solar radiation from average hourly global solar radiations for various months [16, 19, 20, 21, 25] and the methods adopted are recommended for hour wise predictions also but are rarely tested. Liu and Jordan [16] developed study curve between hourly and daily solar radiations through ratio relationship of hourly to daily radiations. The curves are used by Whillier [17] and recommended the same for only clear sky conditions. Benseman and cook [18] suggested to use the curve only for individual day's prediction and hence may not be suitable for long-term determination. Using collected data for five US stations and Liu and Jordan's curve, Collares-Pereira and Rabl [22] developed an analytical expression for the ratio of hourly to daily solar radiation, in terms of sunset hour angle. Orgill and Holland [25] developed relationship between the daily diffuse coefficient and clearness index. There has been a number of competitive studies in which performance of various models is tested and validated [26-40]. Recently a comparative study done by Badescu et.al [41] suggested that ASHRAE 2005 [42] model is best suited for wide applications. This model is a simple model that determines radiations based on incident angle, but its other parameters including direct and diffuse optical depths shall be already known for the specific location. Hence this method is suitable for ASHRAE monitored locations, as optical depths are disclosed by the organization for such locations. Also the number of parameters to be entered in various other suggested models [41] varies significantly, whose values may not be known for certain locations. In India, Chandrasekaran and Kumar [43] studied five years global radiation data of Madras using correlation and compared the annual data with seasonally classified data. It is resulted that the seasonal classified is a better method than annual correlation to determine diffuse and direct components from global radiations. Chandel and Aggarwal [44] have developed a model to predict solar radiation for Shimla (capital city of Himachal Pradesh- state of study area) based on the model developed by using solar radiation data of Delhi.

Hence the objective of this paper is to develop suitable regression mathematical models to predict the hour wise diffuse and direct components of global solar radiations for available data.

## 4. Methodology

The paper uses measured data of one year to establish a relationship between its clearness index ($M_T$) and cloudiness index ($M_D$) for annual, seasonal and hour wise conditions using regression analysis. The relationships are compared with each other for statistical error performance. The most suitable method found is further used to calculate diffused and direct component of global solar radiations of available data for other characteristics years.

## 5. About the site

Himachal Pradesh is a north Indian state. The elevation varies from 350 meter to 6975 meter, having latitude 30º 22' 40" N to 33º 12' 40" N and longitude 75º 45' 55" E to 79º 04' 20" E, and diverse climatic regions ranging from extreme cold climate to Composite/sub-tropical climate [45]. The location selected for this study is a district headquarter town named Hamirpur, located in the southwestern part of the state. It is an urban Centre located 31.63° N, 76.52° E and has an altitude of 765 m. The Koppen classification [46] of the study area is Humid subtropical whereas the based on heating degree day (HDD18) and Cooling Degree Days (CDD10), as suggested by [12,47] is under Warm Humid classification.

### *5.1 Data and instruments used:*

The available data consists of global radiations measured every minute for Hamirpur from September 2011 onwards, but its diffused and direct components are not known and hence cannot be used for weather file. This data is collected using a Kipp & Zonen All Weather Station erected at 3.5 meter height of a mast tower of approximately 20 meters high over the rooftop of the Centre for Energy and Environmental Engineering which is a 9 meter high building at National Institute of Technology Hamirpur [Fig. 2]. The station uses a SP Lite2 pyrometer for global solar radiation measurements. The pyranometer is 889 meters above mean sea level and uses a photodiode detector that gives output to a data logger in Watts per square meter (W/m²). It has a spectral range of 400 to 1100 nm, sensitivity 60 to 100 µV/W/m² and a response time < 500 ns for 95% data. The second set of data (henceforth called measured data) is measured using Kipp & Zonen SOLYS 2 Sun Tracker which is erected on a 1 meter x 1 meter x 1 meter concrete platform on the rooftop of same Centre and is 887 meters above mean sea level [Fig. 3]. It has an integrated GPS receiver to automatically configure location and a Kipp & Zonen CHP 1 pyrheliometer to measure direct normal solar radiations along with two pyranometers to measure global radiations and diffused radiations at horizontal surface. It has a pointing accuracy of < 0.1° passive tracking and < 0.02° active tracking. It measures radiations every minute, which are collected in a computer through the Combilog data logger of the same company. All the instruments are calibrated locally.

**Fig. 2:** Pyranometer on All weather Station

**Fig. 3:** Sun Tracker

For the study, two parameters are used, namely hourly clearness index ($M_T$) and hourly diffuse index ($M_D$), indicative of the clearness of the sky and the proportion of diffuse radiation from global radiations respectively. The measured data of Sun Tracker is used for the development of the model. As suggested by Reindl et al. [48] and De Miguel et al [49] the following data is not included:

- All entries of the day, whose at least one entry is missing.

- Global solar radiation exceeding the extra-terrestrial radiation (MT>1).
- Diffuse fraction MD > 1
- ID>0.8I0
- ID >0.8 I when I > 0.6I0 (limits diffuse index under clear sky condition)
- ID <0.9 I when I < 0.2I0 (limits diffuse index under overcast sky condition)

It resulted in 4662 hours entries out of standard 8760 (24 nos. X 365 days) entries for a year.

## 6 Analysis of data:

As mentioned, the global, diffused and direct radiations are measured in W/m$^2$. The hourly extraterrestrial radiations $I_0$ are calculated using eq. 1 [7].

$$I_0 = \frac{(12.3600)}{\pi} . G_{sc} . \left(1 + 0.033 cos \frac{360.n}{365}\right)$$

$$\left[cos\, \varphi\, cos\, \delta\, (sin\, \omega_2 - sin\, \omega_1) + \frac{\pi(\omega_2 - \omega_1)}{180} sin\, \varphi\, sin\, \delta\right] \quad (1)$$

Where $I_0$ is the hourly extraterrestrial radiation, $G_{(sc)}$ is the solar constant having value 1367 W/m$^2$ (as recommended by the World Radiation Centre), n is no. of day of the year starting from 1st January, $\varphi$ is latitude, $\delta$ is declination and calculated as per eq. 2 given below, $\omega_2$ and $\omega_1$ are hour angles and calculated as per eq.3 given below.

$$\delta = 23.45 . sin\left(360.\frac{284+n}{365}\right) \quad (2)$$

$$\omega_{si} = cos^{-1}[-tan\delta_i \ .\ tan\, \varphi_i] \quad (3)$$

Then hourly clearness index and diffuse index is calculated using eq. 4 and eq. 5 respectively.

$$M_T = {I}/{I_0} \quad (4)$$

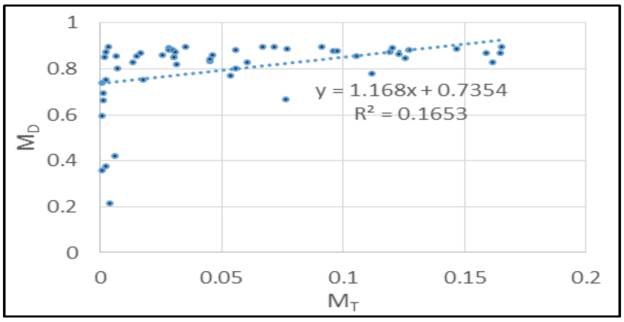
$$M_D = {I_D}/{I} \quad (5)$$

The values of $M_T$ are further classified for overcast, partially cloudy and clear sky conditions. Various studies have adopted different values for monthly averaged daily clearness index ($K_T$) as per their field experiences. For e.g. Orgill and Hollands [25] proposed <0.35, 0.35-0.75 and >0.75 for cloudy, partial cloudy and clear sky respectively. Chandrasekaran and Kumar [43] used <0.24, 0.24- 0.80 and >0.80 whereas Reindl et al. [48] have proposed KT values < 0.2, 0.2-0.6 and > 0.6 for cloudy, partial cloudy and clear sky respectively. Li and Lam [48] and Li, Lau and Lam [51] used KT values < 0.15, 0.15-0.7 and >0.7 to define overcast, partly cloudy and clear sky respectively. Kuye and Jagtap [52] used 0.12-0.35 and > 0.65 for cloudy and very clear skies respectively for Nigeria. Similarly Oliveira et al. [53] used < 0.17, 0.17-0.75 and > 0.75 for cloudy, partial cloudy and clear sky respectively and the same is proposed for this study.

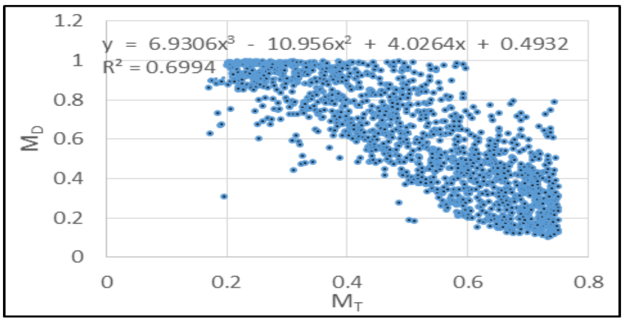
The x-y scattered diagrams are developed for $M_T$ and $M_D$. Further relationship between $M_T$ and $M_D$ is established using suitable regression equations in Microsoft excel 2013 for the followings. The care is taken to obtain most appropriate trendline having the highest value of $R^2$ using either linear or polynomial regression method.

### *5.2 Annual measurements with all sunshine hours*

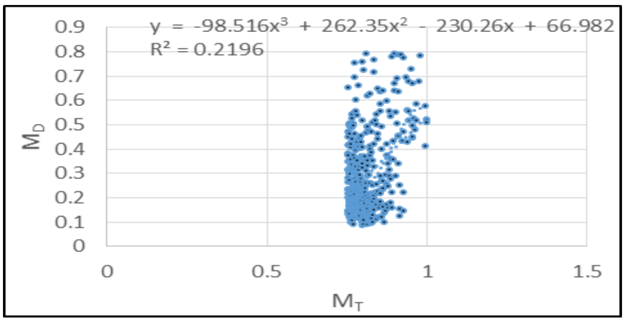
In this method, the complete annual measured data is segregated for range defined above and the x-y scatter plot is obtained [Fig.4]




a) $M_D$ v/s $M_T$ (0.0008<$M_T$< 0.17)




b) $M_D$ v/s $M_T$ (0.17<$M_T$< 0.75)

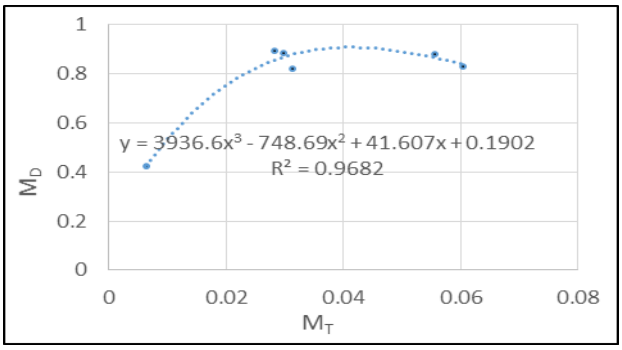



c) $M_D$ v/s $M_T$ (0.75<$M_T$< 0.99)

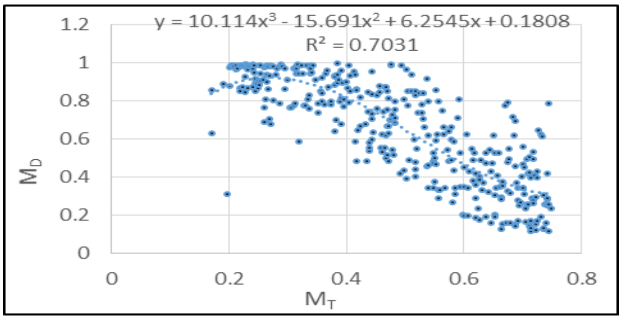
**Fig. 4:**Relationship between MT and MD for annual data

### *5.3 Seasonal measurements*

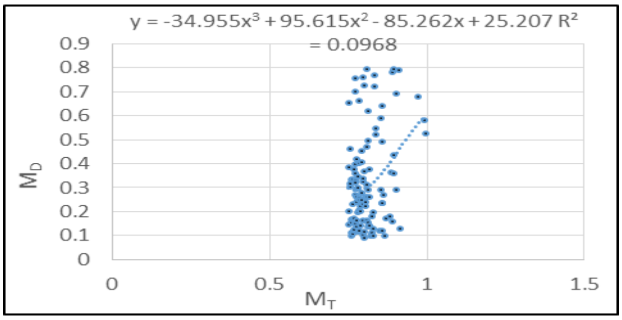
As per Indian Meteorological Department [54], the season classification of the country is winters, pre monsoon, monsoon and post monsoon. The duration considered in this paper is 16th December to 15th March, 16th March to 15th June, 16th June to 15th September and 16th September to 15th December respectively [Fig. 5].



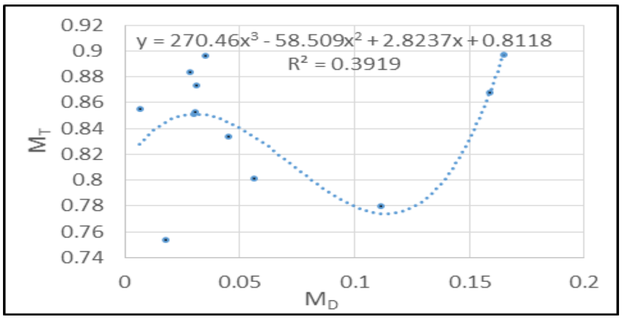

a) MD v/s MT (0.0008<MT< 0.17) for Winter



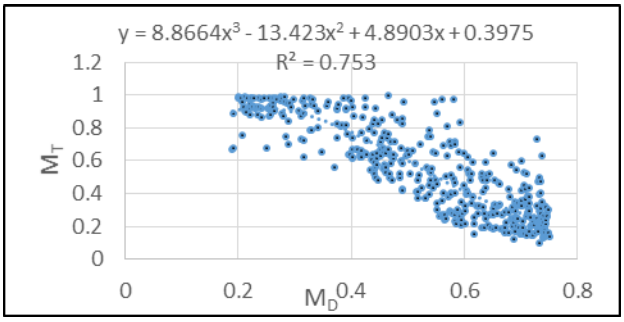

b) MD v/s MT (0.17<MT< 0.75) for Winter



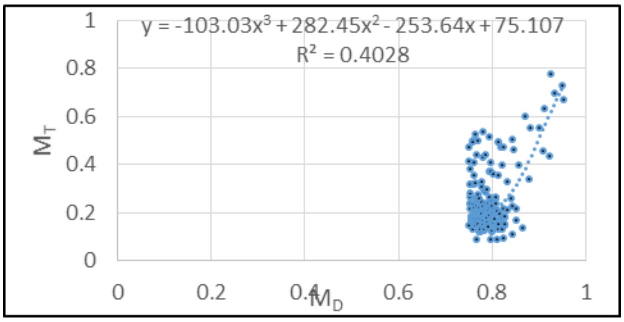

c) MD v/s MT (0.75<MT< 0.99) for Winter



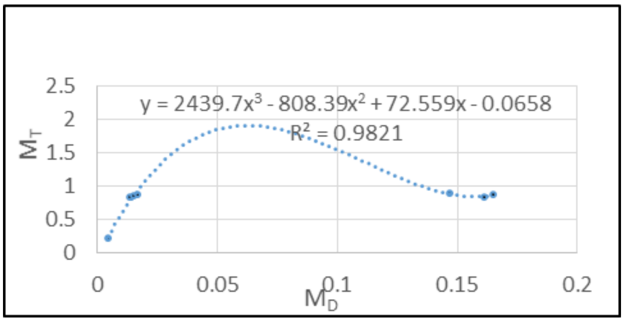

d) MD v/s MT (0.0064<MT< 0.17) for Pre monsoon



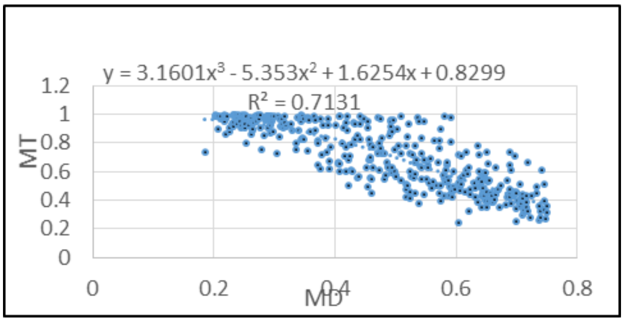

e) MD v/s MT (0.17<MT< 0.75) for Pre monsoon



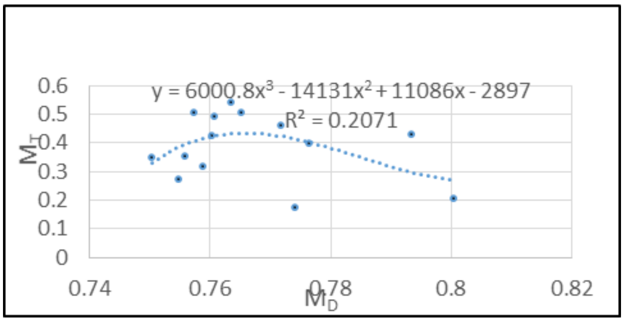

f) MD v/s MT (0.75<MT< 0.99) for Pre monsoon



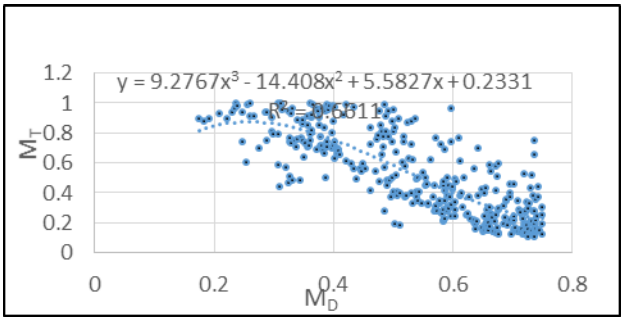

g) $M_D$ v/s $M_T$ ($0.004<M_T<0.17$) for Monsoon



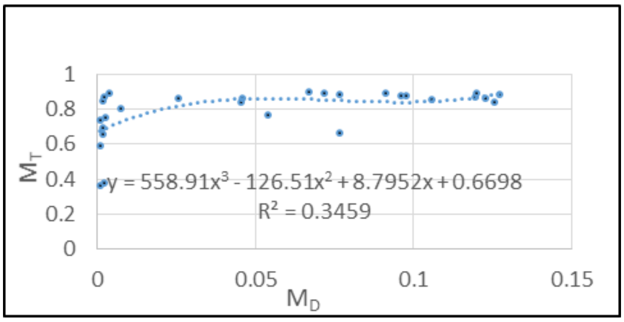

h) MD v/s MT (0.17<MT< 0.75) for Monsoon



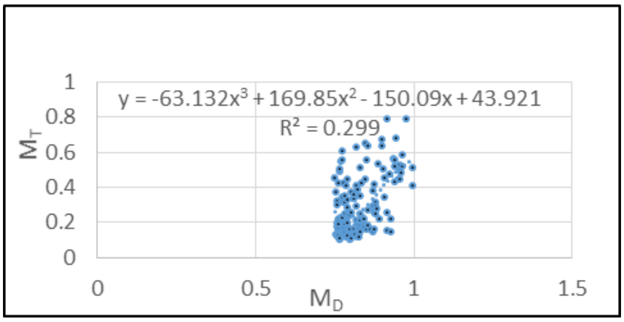

i) MD v/s MT (0.75<MT< 0.99) for Monsoon




j) $M_D$ v/s $M_T$ ($0.0008<M_T< 0.17$) for Post Monsoon




k) MD v/s MT (0.17<MT< 0.75) for Post Monsoon




l) MD v/s MT (0.75<MT< 0.99) for Post Monsoon

**Fig. 5:** Relationship between MT and MD for seasonal data

The value of $R^2$ signifies that the prediction is easier for noon hours when sun angle is almost perpendicular to the surface of the earth and become more difficult during the morning as well as evening hours. The value of $R^2$ is high for 6:00 AM as the number of entries (no. of sunshine days in a year) are much lesser and hence curve fitting the dataset is more accurate. It is found that the x-y scatter of hour wise analysis shows a nonlinear data randomly distributed for $M_T>0.75$ whereas various studies [16-31] shows a constant value for daily average monthly data of $K_D$ for $K_T>0.75$ or such similar values. This is also suggested by Smietana et.al [55].

### *5.4 Hour wise measurements*

Similarly scatter diagrams for each sunshine hours are developed and relationships established between $M_T$ and $M_D$ and equations obtained [Table 1].

## *6.* Results and discussions:

As suggested by Iqbal [23], the performance of the models is validated using mean bias error (MBE), the root mean square error (RMSE) and the Pearson's correlation coefficient (CC) as per eq. 6-8 for which the values obtained are mentioned in Table 2. Apart from these, mean absolute percentage error (MAPE) is also calcuated as per eq. 9.

$$MBE = \frac{\sum_{i=1}^{n}(y_i - x_i)}{N} \quad (6)$$

$$RMSE = \left(\frac{\sum_{i=1}^{n}(y_i - x_i)^2}{N}\right)^{\frac{1}{2}} \quad (7)$$

$$CC = \frac{\sum_{i=1}^{n}(y_i - \bar{y})(x_i - \bar{x})}{[\sum_{i=1}^{n}(y_i - \bar{y})^2][\sum_{i=1}^{n}(x_i - \bar{x})^2]} \quad (8)$$

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{x_i - y_i}{x_i}\right| \quad (9)$$

**Table 1: $M_T$ and $M_D$ relationship equations for annual measurements**

| S. | Hour | Period | Equation | $R^2$ |
|---|---|---|---|---|
| 1 | 6:00 AM | 11th May – 3rd August | $M_T = 2.2675M_D^3 - 2.9336\ M_D^2 + 1.1772\ M_D + 0.838$ | 0.8836 |
| 2 | 7:00 AM | 4th March - 22nd October | $M_T = 6.8641\ M_D^3 - 11.192\ M_D^2 + 4.612\ M_D + 0.4787$ | 0.824 |
| 3 | 8:00 AM | All year | $M_T = 8.9869\ M_D^3 - 15.581\ M_D^2 + 7.2282\ M_D + 0.0113$ | 0.7249 |
| 4 | 9:00 AM | All year | $M_T = 7.696\ M_D^3 - 13.827\ M_D^2 + 6.3508\ M_D + 0.1297$ | 0.8458 |
| 5 | 10:00 AM | All year | $M_T = 6.4145\ M_D^3 - 12.044\ M_D^2 + 5.6071\ M_D + 0.168$ | 0.8538 |
| 6 | 11:00 AM | All year | $M_T = 1.5454\ M_D^3 - 4.2432\ M_D^2 + 1.5625\ M_D + 0.8175$ | 0.9139 |
| 7 | 12:00 PM | All year | $M_T = 3.4948\ M_D^3 - 7.1548\ M_D^2 + 2.8603\ M_D + 0.6084$ | 0.8839 |
| 8 | 1:00 PM | All year | $M_T = -2.7953\ M_D^3 + 2.8825\ M_D^2 - 2.2454\ M_D + 1.3784$ | 0.8255 |
| 9 | 2:00 PM | All year | $M_T = -1.6337\ M_D^3 + 0.0714\ M_D^2 - 0.4425\ M_D + 1.0108$ | 0.8047 |
| 10 | 3:00 PM | All year | $M_T = 6.8459\ M_D^3 - 10.772\ M_D^2 + 3.4913\ M_D + 0.6346$ | 0.8002 |
| 11 | 4:00 PM | All year | $M_T = -0.5108\ M_D^3 - 2.5708\ M_D^2 + 0.8923\ M_D + 0.792$ | 0.719 |
| 12 | 5:00 PM | 28th Feb – 1st November | $M_T = -3.2109\ M_D^3 - 1.8188\ M_D^2 + 1.0417\ M_D + 0.8111$ | 0.7376 |
| 13. | 6:00 PM | 7th May-12th August | $M_T = 105.92\ M_D^3 - 64.301\ M_D^2 + 11.681\ M_D + 0.3582$ | 0.7922 |

**Table 2: Statistical performance of developed models**

| Method | | MBE | RMSE | MAPE | CC | $R^{2*}$ |
|---|---|---|---|---|---|---|
| All annual | | 7.53 | 65.82 | 0.29 | 0 | 0.59 |
| Seasonal | Winter | 9.53 | 61.19 | 0.18 | 0 | 0.57 |
| | Pre monsoon | 9.36 | 64.46 | 0.12 | 0 | 0.65 |
| | Monsoon | 10.88 | 57.23 | 0.05 | 0 | 0.70 |
| | Post monsoon | 3.73 | 65.65 | 0.17 | 0 | 0.54 |
| Hour wise | 6:00 AM | -1.10 | 1.02 | 0.03 | 0 | 0.8836 |
| | 7:00 AM | -9.49 | 18.92 | 0.07 | 0 | 0.824 |
| | 8:00 AM | -10.5257 | 17.72308 | 0.08 | 0 | 0.7249 |
| | 9:00 AM | -13.4871 | 21.48633 | 0.09 | 0 | 0.8458 |
| | 10:00 AM | -28.9503 | 32.08292 | 0.16 | 0 | 0.8538 |
| | 11:00 AM | -17.5127 | 27.38159 | 0.06 | 0 | 0.9139 |
| | 12:00 PM | -27.4952 | 32.87285 | 0.11 | 0 | 0.8839 |
| | 1:00 PM | -16.9063 | 41.3866 | 0.01 | 0 | 0.8255 |
| | 2:00 PM | -30.8094 | 42.11901 | 0.11 | 0 | 0.8047 |
| | 3:00 PM | -17.0254 | 23.78797 | 0.08 | 0 | 0.8002 |
| | 4:00 PM | -26.6423 | 32.27207 | 0.17 | 0 | 0.719 |
| | 5:00 PM | -13.1842 | 15.97471 | 0.11 | 0 | 0.7376 |
| | 6:00 PM | -3.84706 | 4.872953 | 0.12 | 0 | 0.7922 |

* weight averaged, in case of multiple values

Further it is mentioned that the relationship found for daily average monthly may be extended to get daily hour wise estimates, the performance of established models are also checked and compared with established models in Table 3. The various models selected for comparison are Orgill and Holland [25], Reindl et.al. [47], Chandrasekaran and Kumar [43] and Chandel and Aggarwal [44] whose model equations are shown in eq. 10 to 19.

Orgill and Holland:

$$K_D = 1.0 - 0.249\, K_T\ (K_T < 0.35) \qquad (10)$$

$$K_D = 1.557 - 1.84\, K_T\ (0.35 \le K_T \le 0.75) \qquad (11)$$

$$K_D = 0.177\ (K_T > 0.75) \qquad (12)$$

Reindl et.al.

$$K_D = 1.02 - 0.248\, KT\ (KT < 0.3) \qquad (13)$$

$$K_D = 1.45 - 1.67\, KT\ (0.3 \le KT \le 0.78) \qquad (14)$$

$$K_D = 0.147\ (KT > 0.78) \qquad (15)$$

Chandrasekaran and Kumar

$$K_D = 1.0086 - 0.178\, K_T\ (K_T \le 0.24) \qquad (16)$$

$$K_D = 0.9686 + 0.1325\, K_T + 1.4183\, K_T^2 - 10.1862\, K_T^3 + 8.3733\, K_T^4\ (0.24 < K_T \le 0.78) \qquad (17)$$

$$K_D = 0.197\ (K_T > 0.80) \qquad (18)$$

Chandel and Aggarwal

$$M_D = c + d * M_T \qquad (19)$$

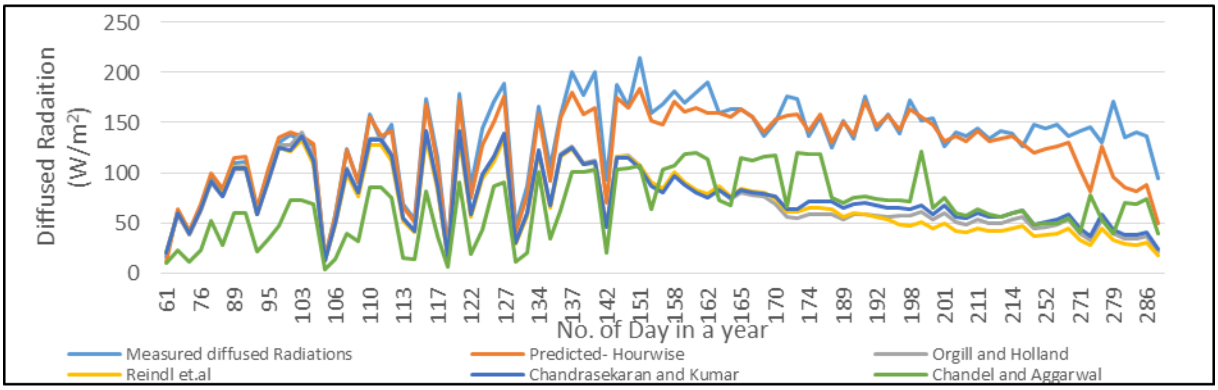
Where c is 0.37, 0.36, 0.36, 0.41, 0.42, 0.55, 0.61, 0.60, 0.42, 0.33, 0.32, and 0.35 for January to December respectively and d is – 0.

It is found that the hour wise model performs better. Diffuse solar radiations are predicted and compared with actual measured values for 6:00 AM, 11:00 AM, 1:00 PM and 6:00 PM using hour wise model and mentioned established models [Fig. 6].

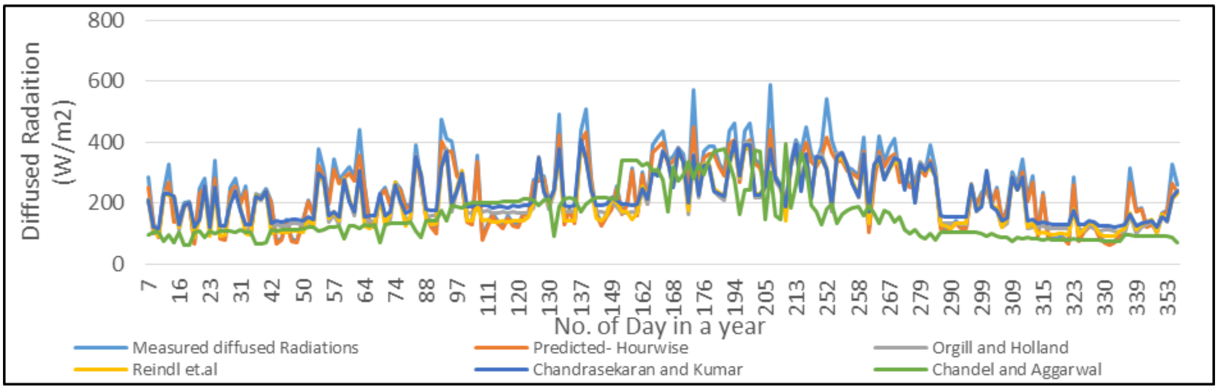
**Table 3: Statistical performance of the developed models with the established models**

| Model | | MBE* | RMSE* | CC* | MAPE* |
|---|---|---|---|---|---|
| All annual | | 7.53 | 65.82 | 0 | 0.29 |
| Seasonal | All seasons | 8.28 | 62.50 | 0 | 0.13 |
| Hour wise | 6:00 AM-6:00 PM | -19.43 | 27.86 | 0 | 0.09 |
| Orgill and Holland | | -11.03 | 66.15 | 0 | 0.96 |
| Reindl et.al. | | -14.83 | 66.82 | 0 | 0.96 |
| Chandrasekaran and Kumar | | -7.59 | 64.81 | 0 | 0.96 |
| Chandel and Aggarwal | | -74.97 | 113.8 | 0 | 0.99 |

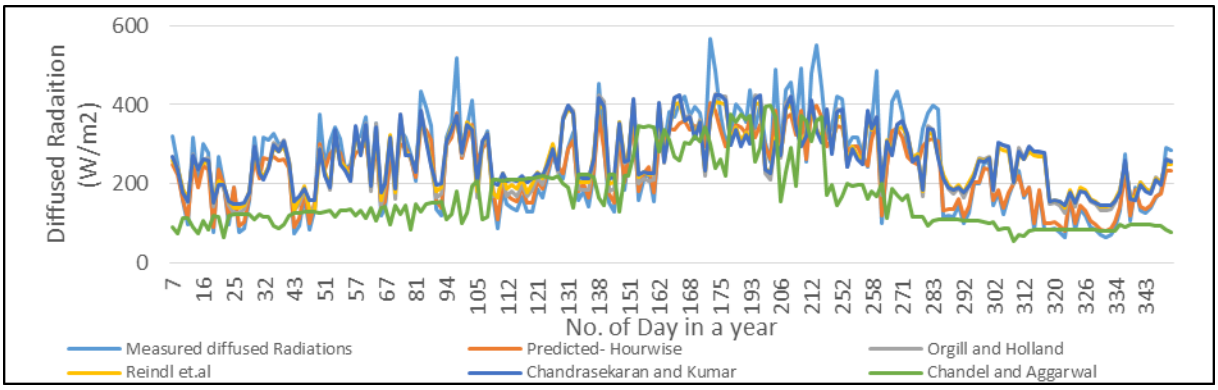
**Note**: *values weight averaged for multiple values



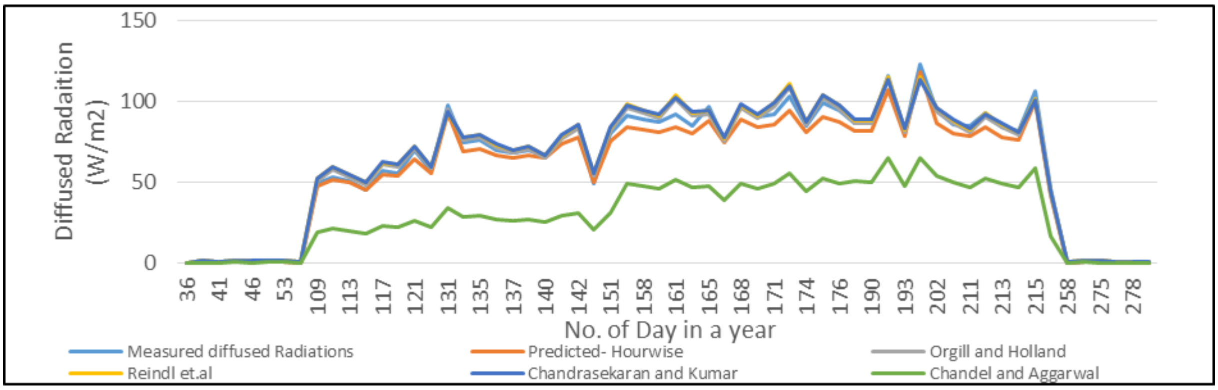

At 7:00 AM




At 11:00 AM




At 1:00 PM




At 6:00 PM

**Fig. 6: Measured v/s Predicted Diffused Radiations using various models**

It is found that hour wise model fits best to the measured data and hence is used to estimate direct horizontal component from the eq. 20

$$I = I_{Dir} + I_D \quad (20)$$

The estimated values of diffuse and direct solar radiation is calculated for global radiation data available from September 2011 till date using hour wise method. Further the component values are obtained for characterstics year 2011 (average), 2013 (coldest) and 2014 (hottest) using the same method and are averaged to get a complete hour wise values for weather file development.

**Conclusion:**

The values of errors show that the hour wise model performs better and can be used to predict the diffuse and direct components of global solar radiations for the given location. The hour wise developed model did not use classified data for fully cloudy, partial cloudy and clear sky conditions in order to reduce further datasets, but considering the same will result in better prediction.

It is found in several studies that the value $K_D$ becomes constant for $K_T$ >0.75 whereas the same could not be seen in this study as actual hour wise values are taken than monthly average hourly values and hence are more unpredictable for linear fitted mathematical models. Further, it is found that each location is unique for solar radiations and its components and hence requires the development of suitable mathematical models rather than using a standard developed model. The increased use of simulation engine for energy analysis requires the development of similar suitable methodology to predict hour wise diffused and direct components of solar radiations rather than monthly averaged hourly, as the same methodology is in demand to prepare weather file which are necessary to run simulations.

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