Solar Tilt Measurement of Array for Building Application and Error Analysis

Abhishek Agarwal*‡, Vineet Kumar Vashishtha**, S.N. Mishra***

*Department of Mechanical Engineering, Kamla Nehru Institute of Technology

**Department of Mechanical Engineering, I.I.T

***Department of Mechanical Engineering, Kamla Nehru Institute of Technology

abhishek_sanjay1@rediffmail.com

‡ Corresponding Author; Abhishek Agarwal, Department of Mechanical Engineering, Kamla Nehru Institute of Technology, Sultanpur, U.P., India,228118, abhishek_sanjay1@rediffmail.com

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Abstract- The optimum angle show some variations when compared with values reported in the literature. The amount of solar radiation incident on a tilted module surface is the component of the incident solar radiation which is perpendicular to the module surface. The array's tilt is the angle in degrees from horizontal. A flat roof has 0 degree tilt and a vertical wall mount has a 90 degrees tilt angle. Whether you are installing solar panel on a flat roof or a pitched roof, the output of the solar PV system would be increased by optimizing the tilt angle. This paper gives the information about the theoretical aspects of choosing a tilt angle for the solar flat-plate collectors used at different locations in India. So the calculations are based upon the measured values of monthly mean daily global and diffuse solar radiation on a horizontal surface. It is shown that nearly optimal energy can be collected if the angle of tilt is varied seasonally, four times a year. Annual optimum tilt angle is found to be approximately equal to latitude of the location. This study determined that PV module oriented towards the South gives the greatest value of electrical energy for the angle of 30^o.

Keywords- optimum tilt angle, PV system performance, solar radiation, solar collector; Clearness index, optimal tilt angle

1. Introduction

Almost all the renewable energy sources originate entirely from the sun. Photovoltaic solar energy conversion is the direct conversion of sunlight into electricity. This can be done by flat plate and concentrator systems. An essential component of these systems is the solar cell, in which the photovoltaic effect the generation of free electrons using the energy of light particles takes place. These electrons are used to generate electricity.

Solar power is energy from the sun and without its presence all life on earth would end. Solar energy has been looked upon as a serious source of energy for many years because of the vast amounts of energy that are made freely available, if harnessed by modern technology.The tilt angle has a major impact on the solar radiation incident on a surface. For a fixed tilt angle, the maximum power over the course of a year is obtained when the tilt angle is equal to the latitude of the location. However, steeper tilt angles are optimized for large winter loads, while lower title angles use a greater fraction of light in the summer. The sun, at noon time, is not always directly on top of us. The sun will be slightly to your south throughout the year, if your location is in the north of 30th latitude in the Northern Hemisphere. The array output is highest, if the array faces directly to the sun at all times. Since the location of the sun moves throughout the day, it is not possible to face directly to the sun unless we use 2-axis solar tracker. But solar tracking is expensive and it is possible to optimize the output by tilting the array at a correct angle.

It is simplest to mount your solar panels at a fixed tilt and just leave them there. But because the sun is higher in the summer and lower in the winter, you can capture more energy during the whole year by adjusting the tilt of the panels according to the season.The amount of radiation flux incident upon a solar collector is mainly affected by the installation angle. Proper design of a collector can increase the irradiation received.[4]

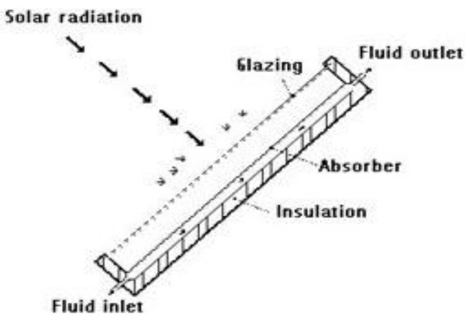

Fig. 1. Glazed flat-plate collector

2. Tilt Measurement

Solar radiation data is usually measured in the form of global radiation on a horizontal surface at the concerned latitude. Flat-plate collectors are tilted so that they capture maximum radiation. Since the flat-plate solar collectors are positioned at an angle to the horizontal, it is necessary to calculate the optimum tilt angle which maximizes the amount of collected energy. It is generally known that in the northern hemisphere, the optimum collector orientation is South facing and that the optimum tilt depends on the latitude and the day of the year. In winter months, the optimum tilt is greater (usually latitude +15°), whilst in summer months the optimum tilt is lower (usually latitude -15°) [1]

For building-integrated applications, the system orientation is also dictated by the nature of the roof or façade in which it is to be incorporated. It may be necessary to trade off the additional output from the optimum orientation against any additional costs that may be incurred to accomplish this. The aesthetic issues must also be considered [2].

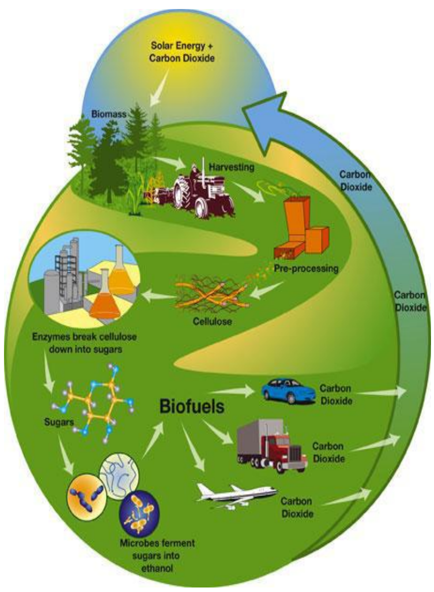

Fig. 2. Energy System

Chen et al. [3] had estimated the monthly optimal installation angle for solar cell in Chiayi, Taiwan, according to the climatology data from 1995 through 1998, by means of genetic algorithm and simulated

Annealing methods. However the climatic conditions elsewhere in Taiwan may differ with Chiayi. In order to build a useful database improving the application of solar energy, it is necessary to study more about what the best installation angle is around Taiwan.

In this study, the daily irradiation of horizontal surface observed in Taiwan.

3. Solar Thermal Collector Overview

The average power density of solar radiation is 100-300 watts a square meter. The net conversion efficiency of solar electric power systems (sunlight to electricity) is typically 10-15 percent. So substantial areas are required to capture and convert significant amounts of solar energy to fulfill energy needs (especially in industrialized countries, relative to today's energy consumption). For instance, at a plant efficiency of 10 percent, an area of 3-10 square kilometers is required to generate an average of 100 megawatts of electricity-0.9 terawatt-hours of electricity or 3.2 pet joules of electricity a year using a photovoltaic system.

4. Solar Radiation

Solar radiation describes the visible and near-visible (ultraviolet and near-infrared) radiation emitted from the sun. The different regions are described by their wavelength range within the broad band range of 0.20 to 4.0 µm (microns). $\boldsymbol{H}=\boldsymbol{H}_{dir}+\boldsymbol{H}_{diff}$ Terrestrial radiation is a term used to describe infrared radiation emitted from the atmosphere. The following is a list of the components of solar and terrestrial radiation and their approximate wavelength ranges:

- Ultraviolet: 0.20 - 0.39 µm
- Visible: 0.39 - 0.78 µm
- Near-Infrared: 0.78 - 4.00 µm
- Infrared: 4.00 - 100.00 µm

Approximately 99% of solar, or short-wave, radiation at the earth's surface is contained in the region from 0.3 to 3.0 µm while most of terrestrial, or long-wave, radiation is contained in the region from 3.5 to 50 µm. outside the earth's atmosphere, solar radiation has an intensity of approximately 1370 watts/meter^2. On the surface of the earth on a clear day, at noon, the direct beam radiation will be approximately 1000 watts/meter^2 for many locations.

a. Beam Radiation: The solar radiation received from the sun without having been scattered by the atmosphere.

b. Diffuse Radiation: The solar radiation received from the sun after its direction has been changed by scattering by the atmosphere.

c. Total Solar Radiation: The sum of the beam and diffuse solar radiation on a surface.

d. Irradiance: The rate at which radiant energy is incident on a surface, per unit area of surface. The symbol G is used for solar irradiance.

e. Insolation-The incident energy per unit area on a surface, found by integration of irradiance over a specified time, usually an hour or a day. Insolation is a term applying specifically to solar energy irradiation. The symbol H is used for insolation for a day. The symbol I is used for insolation for an hour (or other period if specified).

The extraterrestrial radiation on a horizontal surface at any time is $H_o \ = H_{on}\, cos\theta_z$

5. Modeling

Based on the literature survey it is seen that the incident solar radiations on a collector surface are greatest for an optimal tilt angle of the collector at a particular region which is also not constant throughout the year. To obtain maximum power output from the solar collector system it is desirable to tilt the collector to that tilt angle at which the incident solar radiations are maximum.

To optimize capture of solar panels a tilt angle of 28° - 30° is recommended. However, tilt angles between 20° - 60° are possible without great yield losses. Increasing the tilt angle favors energy production in the winter, while decreasing the tilt angle favours energy production in the summer. As most published meteorological data give the total radiation on horizontal surfaces, correlation procedures are required to obtain insolation values on tilted surfaces from horizontal radiation. Monthly average daily total radiation on a tilted surface (HT) is normally estimated by individually considering the direct beam (HB),diffuse (HD) and reflected components (HR) of the radiation on a tilted surface. Ahmad M. Jamil and Tiwari G.N. [5] analyzed the theoretical aspects of choosing a tilt angle for the solar flat-plate collectors used at ten different stations in the world and makes recommendations on how the collected energy can be increased by varying the tilt angle. For Indian stations, the calculations are based upon the measured values of monthly mean daily global and diffuse solar radiation on a horizontal surface. For other stations, the calculations are based upon the data of monthly mean daily global solar radiation and monthly average clearness index on a horizontal surface. It was shown that nearly optimal energy can be collected if the angle of tilt is varied seasonally, four times a year.

The dependence of extraterrestrial radiation on time of year is indicated by Duffie J.A. and Beckman W. A. [8]:

$$G=G_{sc}\left(1+0.033cos\frac{360n}{365}\right)$$

Mubiru J. and Banda E.J.K.B. [6] explored the possibility of developing a prediction model using artificial neural networks (ANN) A mathematical model is used to estimate the total (global) solar radiation on a tilted surface and to determine the optimum tilt angle for a solar collector in Izmir, Turkey. Total solar radiation on the solar collector surface with an optimum tilt angle is computed for specific periods.

Joakim Widén [7] mentioned the models of solar radiation, daylight and solar cells as a chapter in his thesis. He described the models implemented for calculating the daylight level and the power output from PV system, to be used in further simulations of domestic (Sweden) electricity demand, he gave a brief overview of models, then he described in his chapter how to determine incident radiation on a tilted plane from radiation components measured on a horizontal plane, then he described the daylight model and PV system model

Isotropic Models

- *Liu and Jordan model [12]*(1962)

Rd= [3 + cos (2β)] / 4

- *Badescu model* (2002)

Rd= [3+ cos 2β] /4

Anisotropic Models

- *Hay model[11]* (1979)

$$R_d = \frac{H_b}{H_\circ} R_d + \left(1 - \frac{H_b}{H_\circ}\right)[(1+cos\beta)/2]$$

- *Reindl et al. model* (1990)

$$\mathrm{R_d} = \frac{\mathrm{H_b}}{\mathrm{H_\circ}}\mathrm{R_b} + \left(1 - \frac{\mathrm{H_b}}{\mathrm{H_\circ}}\right)[(1+\cos\beta)/2]\left[1 + \sqrt{\mathrm{H_b/H}}\,\sin^3(\beta/2)\right]$$

6. Intension

One of the objectives of this research is to provide technical information about tilt angle and orientation of PV Panels for both Architectures who interests in Building-Integrated Photovoltaic applications and Practitioner Engineers who interests in the utilization of renewable energy in India to improve and enhance the efficiency of PV System used in their designs with reduced cost. Daily and monthly Optimum slope angles.

i. Seasonal Optimum tilt angles.
ii. To compare the different model.

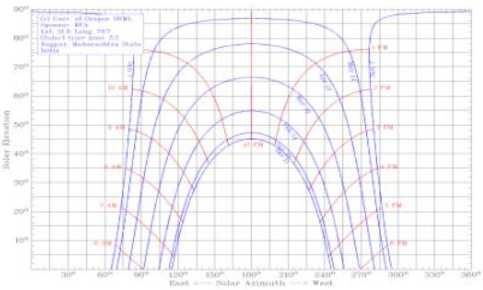

Fig. 3. Sun Path for Nagpur along the year

The sunset hour angle ω for any day (n) of the year can be obtained as follows. The total daily irradiation on a horizontal plane, H, is the combination of two

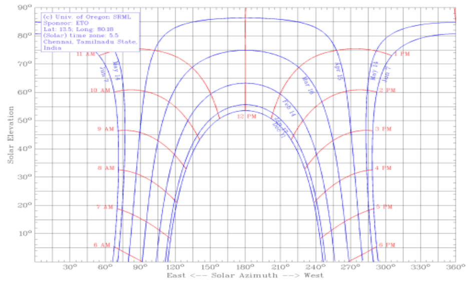

Fig. 4. Sun Path for Chennai along the year

Components- the direct (beam) irradiation and the diffuse irradiation from the sky. Orientation of solar collector in space is the main factor influencing the quantity of absorbed solar radiation energy. In the case with optimal angles of a solar collector, we will have the maximum of solar radiant energy.

The optimal angles depend on the geographical position and on the investigation period (day, week, month, etc.) when the position of a solar collector will be stationary. It is very important, because the trajectory of the sun changes. The intensity of solar radiation energy, sunlight duration per day and per year change as well.

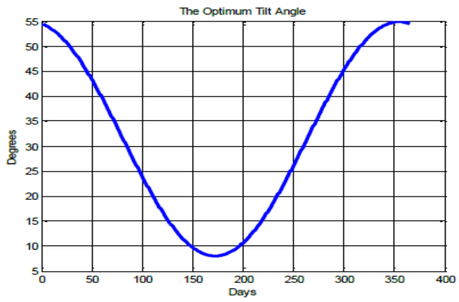

Fig. 5. Optimal Tilt Vs Days

Emanuele [9] found in his paper a relationship between the optimum tilt angle and the geographic latitude. Furthermore, he found that the optimum tilt angle values for winter months were very different than those relative to summer months, so he suggested the idea of planning semi fixed solar panels.

Total radiation on a tilted surface, can thus be expressed as

$$H_t = \left(H - H_{diff}\right)R_b + H\rho\left(1-\cos\beta\right)/2 + H_d R_d$$

7. Site Analysis and Results

Understanding solar radiation data and the amount of solar energy intercepts specific area are essential for modeling solar energy system and covering the demand. Therefore, precise knowledge of historical global solar radiation at a location of study is required. The following is data retrieved from Meteorological Station Data.

Table. 1. Horizontal Irradiation data for Nagpur

Month	kWh/m^2/d
Jan	4.62
Feb	5.50
Mar	6.22
Apr	6.77
May	6.59
Jun	4.95
Jul	3.89
Aug	3.72
Sep	4.40
Oct	5.13
Nov	4.80
Dec	4.49
Annual	5.09

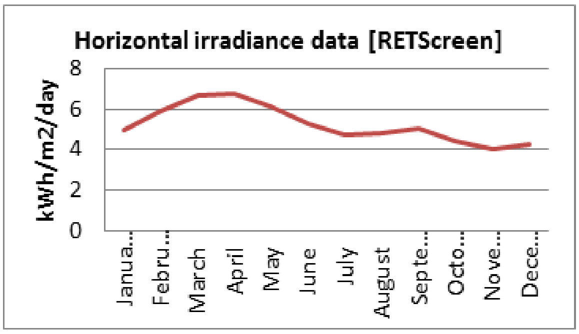

Fig. 6. Daily solar radiation for Nagpur- horizontal

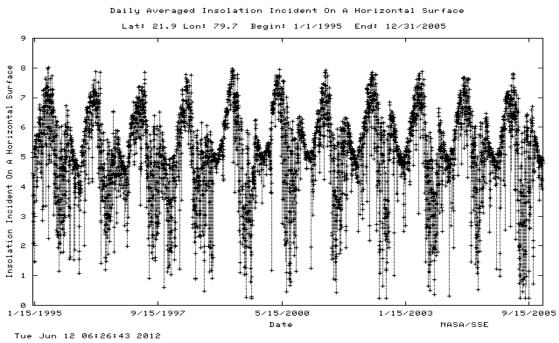

Fig. 7. Daily Averaged Insolation Incident On A Horizontal Surface-Nagpur, India.

Table 2. Horizontal Irradiation data for Chennai

Month	kWh/m^2/d
Jan	4.93
Feb	5.89
Mar	6.64
Apr	6.72
May	6.12
Jun	5.24
Jul	4.73
Aug	4.80
Sep	5.01
Oct	4.42
Nov	4.06
Dec	4.24
Annual	5.23

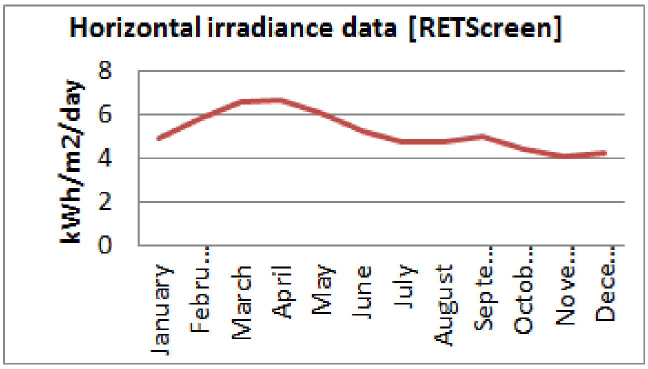

Fig. 7. Daily solar radiation Data for Chennai- Horizontal

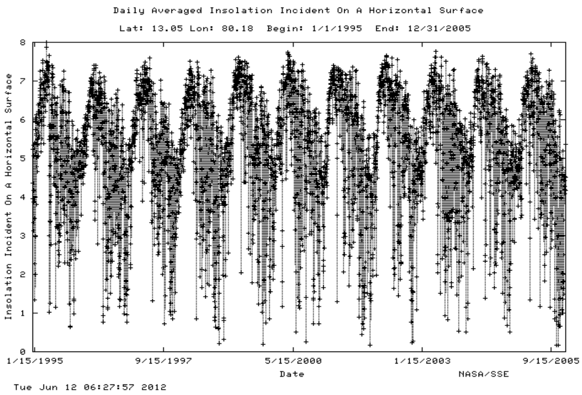

Fig. 8. Daily Averaged Insolation Incident on a Horizontal Surface-Chennai, India.

Tasi et.al [10] implemented a generalized photovoltaic model using Matlab software package which can be representative of PV cell, module, and array for easy use on simulation platform. Their proposed model is designed with a user-friendly icon and a dialog box like Simulink block libraries. His model will be helpful to develop similar model taking into account the variation of irradiation and temperature, also to be used in several power systems. Fig shows the beam radiation dominates throughout the year where the maximum beam radiation reaches in the month of May (**2.3066**$\times$ $\mathbf{10^7}\boldsymbol{W}/\,\mathbf{m2}$ day) whereas the least amount of beam radiation occurs in the month of December (1.1026 $\times$ $10^7\boldsymbol{W}/\,\mathbf{m2}$ day).

In rainy season the beam radiation decreases whereas the diffuse radiation increases still the beam radiation Chennai shows similar trends as that of Nagpur is much higher than the diffuse radiations in Nagpur.

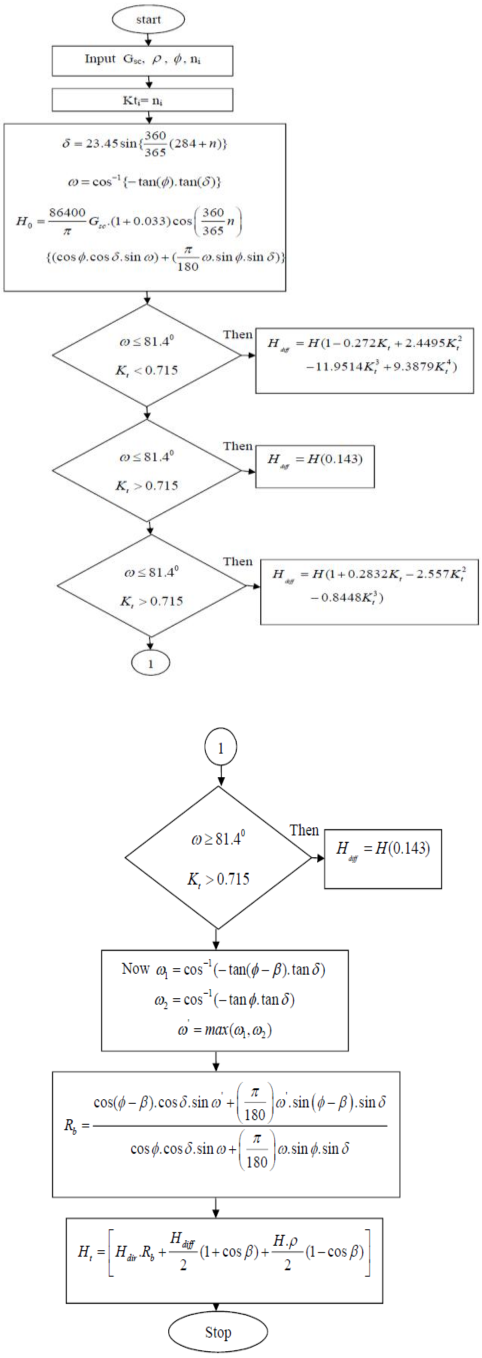

Fig. 9. Flow Chart for calculation

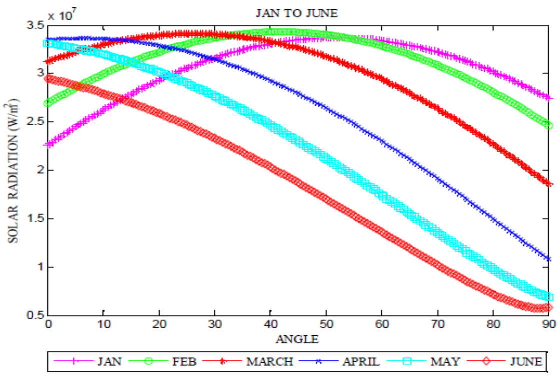

Fig. 10. Monthly-average daily solar radiation availability of tilted surfaces at Nagpur

The average daily total solar radiation at Nagpur on a south facing surface as the angle of tilt is varied from 0° to 90° in steps of 0.5°. It is clear from these graphs that a unique β_{opt} exists for each month of the year for which the solar radiation is at a peak for the given month. The optimum angle of tilt of a flat plate collector in January is 52° and the total monthly solar radiation falling on the surface at this tilt is 3.3673×10^7 W/m^{2}day. The optimum tilt angle in June goes to a minimum of zero degree and the total monthly solar radiation at this angle is 2.9468×10^7 W/m^{2}day. The optimum tilt angle then increases during the winter months and reaches a maximum of 53.5° in December which collects 3.4490×10^7 W/m^{2}day of solar energy monthly.

The average daily total solar radiation at Chennai on a south facing surface as the angle of tilt is varied from 0° to 90° in steps of 0.5°. It is clear from these graphs that a unique β_{opt} exists for each month of the year for which the solar radiation is at a peak for the given month. The optimum angle of tilt of a flat-plate collector in January is 44.5° and the total monthly solar radiation falling on the surface at this tilt is 3.3610×10^7 W/m^{2}day.

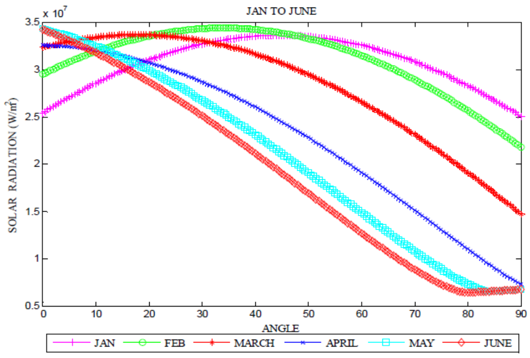

Fig. 11. Monthly-average daily solar radiation Availability of tilted surfaces at Chennai.

The optimum tilt angle in May goes to a minimum of zero degree and the total monthly solar radiation at this angle is 3.4337×10^7 W/m^{2}day. The optimum tilt angle then increases during the winter months and reaches a maximum of 46° in December which collects 2.8320×10^7 W/m^{2}day of solar energy monthly.

Table 3. Optimum Tilt Angle βopt for Each Month of the Year at Nagpur

Months	Liu & Jordan Model		Reindl Model		Hay Model		Badescu Model	
	β_{opt} (°)	$H_t(\beta_{opt})$ 10^7 W/m^{2}day	β_{opt} (°)	$H_{t(\beta_{opt})}$ 10^7W/m^{2}day	β_{opt} (°)	$H_{t(\beta_{opt})}$ 10^7W/m^{2}day	β_{opt} (°)	$H_{t(\beta_{opt})}$ 10^7W/m^{2}day
Dec	53.5	3.4490	55	3.6664	54	3.6509	53.5	3.4111
Jan	52	3.3673	53.5	3.5500	53	3.5442	51.5	3.3295
Feb	42	3.4273	43.5	3.5591	43	3.5554	41	3.3915
Mar	26.5	3.4117	28	3.4670	27.5	3.4658	25.5	3.3920
Apr	6.5	3.3644	7	3.3677	7	3.3677	6.5	3.3630
May	0	3.3094	0	3.3094	0	3.3094	0	3.3094
Jun	0	2.9468	0	2.9468	0	2.9468	0	2.9468
Jul	0	2.3335	0	2.3335	0	2.3350	0	2.3335
Aug	0	2.2165	0	2.2165	0	2.2165	0	2.2165
Sep	17	2.3785	18.5	3.4004	18	3.3993	15	2.3575
Oct	36.5	2.9437	35.5	3.0216	37.5	3.0209	31.5	2.9170
Nov	48.5	3.2876	50.5	3.4507	50	3.4455	48	3.2509
Average	**23.54**	**3.0363**	**24.29**	**3.1907**	**24.16**	**3.1881**	**22.71**	**3.0182**

Table indicates yearly optimum tilt angle is 23.54° and solar radiation is 3.0363×10^7 W/m^{2}day by Liu and Jordan model and optimum tilt angles are 24.29°, 24.16° and 22.71° solar radiation are 3.1907×10^7W/m2day, 3.1881×10^7W/m2day, 3.0182×10^7W/m2day by Reindl,Hay and Badescu models respectively for Nagpur.

Table 4. Optimum Tilt Angle βopt for Each Month of the Year at Chennai

Months	Liu & Jordan Model		Reindl Model		Hay Model		Badescu Model	
	β_{opt}(°)	$H_t(\beta_{opt})10^7$ W/m^{2}day	β_{opt}(°)	$H_{t(\beta_{opt})}$ 10^7W/m^{2}day	β_{opt}(°)	$H_{t(\beta_{opt})}$ 10^7W/m^{2}day	β_{opt}(°)	$H_{t(\beta_{opt})}$ 10^7W/m^{2}day
Dec	46	2.8320	48	2.9508	47	2.9441	45.5	2.7978
Jan	44.5	3.3610	46.5	3.4973	46	3.4924	43.5	3.3242
Feb	34	3.4381	35.5	3.5271	35	3.5246	33	3.4092
Mar	18	3.3866	19	3.3917	18.5	3.3913	17	3.3567
Apr	0	3.2591	0	3.2591	0	3.2591	0	3.2591
May	0	3.4337	0	3.4337	0	3.4337	0	3.4337
Jun	0	3.4227	0	3.4227	0	2.4227	0	3.4227
Jul	1	3.7983	3	3.2983	2.5	3.2983	3.5	3.2983
Aug	4	3.2591	7	3.2627	6.5	3.2627	5.5	3.2627
Sep	10	3.1546	10.5	3.1618	10	3.1617	9.5	3.1516
Oct	28.5	3.0126	30	3.0645	29.5	3.0627	27	2.9930
Nov	41.5	2.4634	43	3.0619	42.5	3.0573	40	2.9335
Average	**18.95**	**3.2351**	**20.20**	**3.2776**	**19.79**	**3.2758**	**18.70**	**3.2202**

Table indicates yearly optimum tilt angle is 18.95° and solar radiation is 3.2351× 〖10〗 ^7 W/m2day by Liu and Jordan model and optimum tilt angles are 20.20°, 219.79° and 18.70° solar radiation are 3.2351× 〖10〗 ^7 W/m2day , 3.2758× 〖10〗 ^7 W/m2day , 3.2202× 〖10〗 ^7 W/m2day by Reindl, Hay and Badescu models respectively for Chennai.

The fixed tilt angle for each season was evaluated as an average of monthly optimum tilt angles for a period of three months. The seasonal variation of optimum angle (βopt(s)) for different location consider in the study. The seasonal optimum tilt angle for

Chennai is minimum as compared to other locations in winter, spring and autumn. The seasonal optimum tilt angle for Nagpur goes to 0° for the summer.

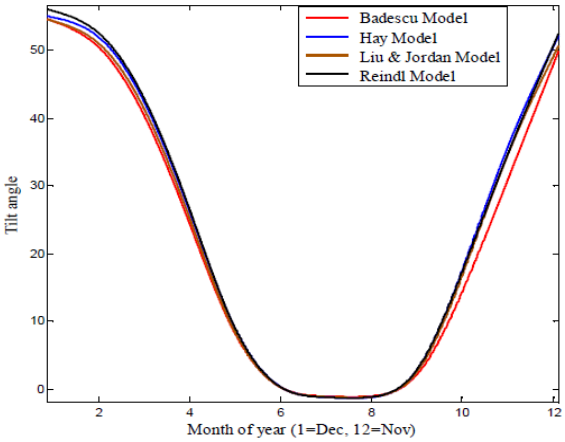

Fig. 12. Comparison of Monthly optimum tilt angle for Nagpur

Therefore comparison of monthly optimum tilt angle for Nagpur using different models which also indicate that the Badescu model is appropriate for Nagpur to find the optimum tilt angle, it also indicate that the monthly optimum tilt angle goes to zero for the month of May June and July for Nagpur consider in the studies. And comparison of monthly optimum tilt angle for Chennai using different models which also indicate that the Badescu model is appropriate for Chennai to find the optimum tilt angle, it also indicate that the monthly optimum tilt angle goes to zero for the month of May June and July for all the Chennai in the studies.

8. Conclusion

The seasonal optimum tilt angles for Chennai is minimum as compared to other locations in winter, spring and autumn but in summer Nagpur goes to minimum seasonal optimum tilt angle. The optimum tilt angle in June goes to a minimum zero degree as indicated by all the models.

On the basis of the above mentioned one can say that:

1. Solar module oriented towards the South gives the greatest values of electrical energy for all the chosen angles.
2. Solar module oriented towards the South for the angle of 30° generates the greatest registered value for electrical energy. This is an optimal tilt angle in the summer
3. Parametric study for evaluating the sensitivity of optimum tilt angle to radiation rate, solar declination, effect of wind etc. can be carried out.
4. Pecuniary assessment can be carried out using a variety of techniques such as net present value, unit cost of electricity and internal rate of return for a power plant.
5. When the sun's rays fall normally on the module's surface, the incident sunlight power is maximum.

Appendices

H_d	Monthly average daily diffuse radiation on a horizontal surface
G_{sc}	Solar constant
G	Extraterrestrial radiation on the plane normal
m	Air mass K.g.
n	Day number of the day of year starting from the first January
Opt	Optimal angle
L	Longitude
β	Tilt of the surface from horizontal
ρ	Ground reflectance (≈ 0.2)
ϕ	Latitude angle
δ	Solar declination
ω	Sunset hour angle
ω'	Sunset hour angle for tilted surface for the mean day of the month
γ	Surface azimuth angle
β_{opt}	Optimum tilt angle
θ_z	Zenith angle
θ	Angle of incidence
A	Array surface area(m^2)
H_O	Extraterrestrial radiation on horizontal surface
H_{on}	Extraterrestrial radiation at normal surface
H_{dir}	Monthly average daily direct radiation on a horizontal surface
H_{diff}	Monthly average daily diffuse radiation on a horizontal surface
H_{refl}	Monthly average daily ground reflected radiation on a horizontal surface
H_{sc}	Solar constant =1367 w/m^2
H	Monthly average daily global radiation on a horizontal surface
Ho	Monthly average daily extraterrestrial radiation on a horizontal surface

Error Analysis- Method Formodel Evaluation

In order to compare the calculated results with the experimental measurements, such kinds of error have been calculated by **[4]-**

a. Coefficient of determination (r^2)

The coefficient of determination, r^2, is useful because it gives the proportion of the variance (fluctuation) of one variable that is predictable from the other variable. The coefficient of determination is the ratio of the explained variation to the total variation.The coefficient of determination is such that $0 \le r^2 \le 1$,

$$r^2 = \frac{\sum_{i=1}^{n} (c_i - c_a)(m_i - m_a)}{\sqrt{\left[\sum_{i=1}^{n} (c_i - c_a)^2\right]\left[\sum_{i=1}^{n} (m_i - m_a)^2\right]}}$$

b. Root mean square deviation (RMSD)

The root-mean-square deviation (RMSD) or root-mean-square error (RMSE) is a frequently used measure of the differences.

$$RMSD = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (c_i - m_i)^2}$$

c. Mean bias error (MBE)

Mean bias error (MBE) the mean bias error-

$$MBE = \frac{1}{n}\sum_{i=1}^{n} (c_i - m_i)$$

d. t-statistic (t-stat) method

To determine whether or not the equations estimates are statistically significant, i.e., not significantly different from their actual counterparts, at a particular confidence level.

$$t\text{-}stat = \sqrt{\frac{(n-1)MBE^2}{RMSD^2 - MBE^2}}$$

Results1 -

Table 5. Values from Table-3 for for Nagpur

$\sum(C_i\text{-}C_a)(m_i\text{-}m_a)$	$\sum (C_i\text{-}C_a)^2$	$\sum (m_i\text{-}m_a)^2$	$\sum (C_i\text{-}m_i)^2$	$\sum(C_i\text{-}m_i)$	n
5297.8958	5397.7292	5221.2292	31.5	10	2

Table 6. obtained values for errors

Coefficient of determination (r^2)	RMSD	Mean Bias Error	t-stat
0.013810999	1.620185	0.8333	1.9891688

Result 2-Reference to the values of $\boldsymbol{\beta}_{opt}$

Table7. Values from Table-4 for for Chennai

$\sum (C_i\text{-}C_a)(m_i\text{-}m_a)$	$\sum (C_i\text{-}C_a)^2$	$\sum (m_i\text{-}m_a)^2$	$\sum (C_i\text{-}m_i)^2$	$\sum(C_i\text{-}m_i)$	n
3833.765	3914.73	3602.23	16.5	3	12

Table 8. obtained values for errors

Coeff. of determination (r^2)	RMSD	Mean Bias Error	t-stat
0.0170099	1.17260394	0.25	0.723746

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