SOLAR POWER OUTPUT WITH OPTIMUM TILT ANGLE USING MATLAB

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***Abstract:** The Tilt angle in a solar energy system is one of the important parameters for capturing maximum solar radiation falling on the solar panels. This angle is site specific as it depends on the daily, monthly and yearly path of the sun. An accurate determination of optimum tilt angle for the location of interest is essential for maximum energy extraction from the system. A numerous methods are being used for determining the tilt angle at different locations worldwide. Keeping in view the relevance of the optimum tilt angle in energy production and reducing the cost of solar energy systems, the present study has been undertaken. The study shows that for maximum energy gain, the optimum tilt angle for solar system must be determined accurately for each location. This review will be useful for designers and researchers to select suitable methodology for determining optimum tilt angle for solar systems at any site.*

Keywords: Solar radiation, Tilt angle, solar geometry.

1. INTRODUCTION

The most significant feature of renewable energy is its plentiful supply. It is infinite. Renewable energy sources are hygienic sources of energy that have a much lesser negative environmental impact than conventional fossil energy technologies. Most renewable energy investments are spent on materials and personnel to build and maintain the facilities, rather than on costly energy imports. With technological advancements in mass communication, people have now become aware of the demerits of burning fossil fuels. Renewable energy is the need of the hour. Its clean and sustainable nature has compelled the human beings to think seriously about it. Scientists and Engineers, around the world, are continuously working and researching in this domain. They are finding new ways to use these sources of energy effectively. Global warming is a huge hazard which is being caused by burning of coal, oil and natural gas. It is very harmful for the planet and the living beings on it. Moreover, fossil fuels are a cause of many unfortunate mishaps in the past as described before. To put an end to this apocalypse; we must resort to renewable sources.

This is because they are cleaner and do not produce poisonous harmful gases. Moreover, fossil fuels are finite. They will certainly end one day. Therefore, before the crucial stage comes up, experts of energy sectors must maintain a positive attitude in this regard and should try their level best to replace fossils fuels with renewable energy sources as the main sources of generating electricity.

2. SOLAR RADIATION ON THE EARTH'S SURFACE

As the solar radiation reaches the atmosphere of the earth, it is scattered, reflected and absorbed by atmospheric particles. As a result, only a portion of the solar radiation outside the earth's atmosphere, i.e., the extra-terrestrial

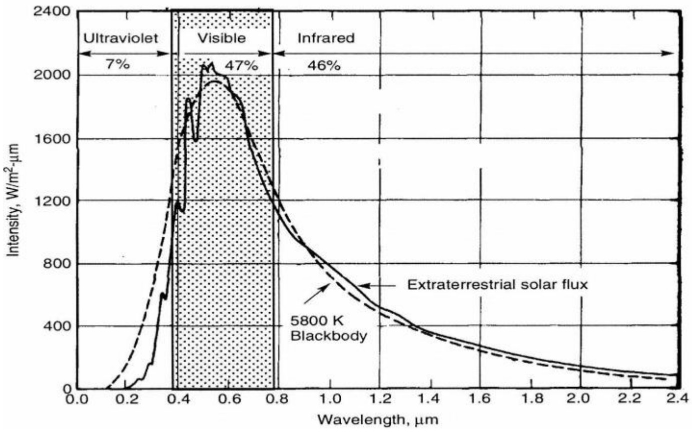

Figure 1: Radiation Spectrum

The extra-terrestrial spectrum and the spectrum of a blackbody at 5800 K. Image reproduced from. Radiation, actually reaches the surface of the earth. This portion, the terrestrial radiation, varies from less than 50% to 70%, depending on the position of the sun and the clearness of the sky. In this section the extra-terrestrial radiation is first defined, and then the terrestrial radiation, consisting of three components, is discussed.

2.1 EXTRA-TERRESTRIAL RADIATION

The extra-terrestrial radiation is defined as the radiation that passes perpendicularly through an imaginary surface just outside the earth's atmosphere. It varies from day to day, depending on the distance between the sun and the earth. The extra-terrestrial radiation, I0 (W/m2), on each day of the year is given.

$$I_0 = \text{SC.}\left[1 + 0.034\ \cos\frac{2\pi n}{365}\right]$$

Where SC is the solar constant and n is the day number (starting from the 1st of January). The solar constant is an estimate of the average annual extra-terrestrial radiation, having a generally accepted numerical value of 1377 W/m2.

2.2 TERRESTRIAL RADIATION

There are two types of radiations:

1) Beam radiation.
2) Diffuse radiation.

Beam or direct radiation
Solar radiation received at earth surface without changes of direction i.e. in the line with the sun.

Diffuse radiation
The radiation received by the earth, from all parts of the sky hemisphere (after being subjected to the scattering in the atmosphere)

2.3 SOLAR GEOMETRY

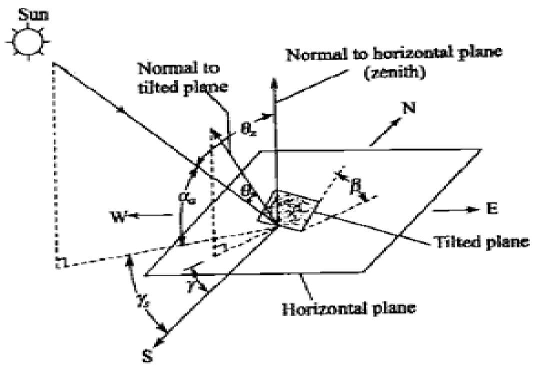

Figure 2: Geometrical view

- ***Declination angle(δ):***

It is the angle made by the line joining the centre of the sun and the earth with the projection of this line on the equatorial plane.
$\delta = 23.45 * \sin(360*(284 + n)/365)$

- ***Hour Angle (ωs):***

It is the angular measure of time and it is equivalent to 15 degrees per hour. It also varies from -180°to +180°
$\omega s = \cos^{-1}(-\tan\phi \tan\delta)$

- ***Slope(β):***

It is the angle made by the plane surface with the horizontal. It can vary from 0 to 180°

- ***Angle of incidence(θ):***

It is the angle between an incident beam of flux and the normal to a plane surface.

- ***Latitude(ϕ):***

The latitude is the angle made by the radial line joining the location to the centre of the earth with the projection of the line on the equatorial plane.

- ***Solar azimuth angle(γs):***

It is the angle made in the horizontal plane between the horizontal line due south and the projection of the line of sight of the sun on the horizontal plane.

- ***Surface azimuth angle(γ):***

It is the angle made in the horizontal plane between the horizontal line due south and the projection of the normal to the surface on the horizontal plane.

- ***Zenith angle (θz):***

It is the angle made by the sun's rays with the normal to a horizontal surface.

- ***Solar altitude angle(αa):***

It is the complement of the zenith angle

2.4 TILT FACTOR

Tilt factor is defined as the angle made by the ground surface to the surface of the solar photo voltaic plate is called tilt angle.

For the case of tilted surface facing south is

$$\cos\theta = \sin\delta \sin(\theta - \beta) + \cos\delta \cos\omega \cos(\phi - \beta)$$

While for the horizontal surface

$$\cos\theta_z = \sin\Phi \sin\delta + \cos\Phi \cos\delta \cos\omega$$

Hence tilt factor for beam radiation is

$$r_b = \frac{\cos\theta}{\cos\theta_z} = \frac{\sin\delta \sin(\emptyset - \beta) + \cos\delta \cos\omega \cos(\emptyset - \beta)}{\sin\emptyset \sin\delta + \cos\emptyset \cos\delta \cos\omega}$$

Similarly, expressions for RB can be derived for other situations in which the tilted surface is oriented in a different direction.

The tilt factor RD for diffuse radiation is the ratio of the diffuse radiation falling on the tilted surface to that falling on a horizontal surface. The value of this tilt factor depends upon the distribution of diffuse radiation over the sky and on the portion of the sky dome seen by the tilted surface. Assuming that the sky is an isotropic source of diffuse radiation, we have for a tilted surface with a slope β,

$$RD=(1+\cos\beta/2)$$

Total radiation for the horizontal surface is:

$$HT = HB + HD$$

Now total radiation for tilted surface is:

$$HT = HB\ RB + HD\ RD$$

The tilted surface also sees ground or other surroundings and if those surrounding have a diffuse reflectance of ρ for solar radiation, the reflected radiation from the surrounding on the surface from total solar radiation.

ρ=0.2 when there is no snow.
=0.7 when there is a snow cover.

Month	Declination angle δ degrees (°)	Optimum tilt angle β(degrees(°)	Total Irradiation tilted collector surface (Wh/m²/day)
January	-20.9	34.9	7047
February	-13	27.02	7457
March	-2.4	16.48	7453
April	9.4	4.65	7075
May	18.8	-4.72	6783
June	23.1	-9.02	6082
July	21.2	-7.11	5438
August	13.5	0.61	5625
September	2.2	11.85	5743
October	-9.6	23.6	5413
November	-18.9	32.98	5703
December	-23	37.11	6191

Table 1: Monthly Total Irradiance Analysis

Month	Season	Optimum tilt angle β(degrees(°)	Total Irradiation tilted collector surface (Wh/m²/day)
March	Spring	5.4	7168
April			7078
May			6680
June	Summer	-5.1	5998
July			5410
August			5688
September	Autumn	22.8	6046
October			5367
November			5160
December	Winter	33	5818
January			6817
February			7788

Table 2: Seasonal Total Irradiance Analysis

Month	Optimum tilt angle β(degrees(°)	Total Irradiation tilted collector surface (Wh/m²/day)
January	14	6369
February		7140
March		7437
April		6909
May		6220
June		5453
July		5027
August		5421
September		5729
October		5331
November		5329
December		5542

Table 3: Yearly Total Irradiance Analysis

Month	Total Irradiation tilted collector surface (Wh/m²/day)		
	Fixed Tilt angle	Seasonal Optimum Tilt	Monthly Optimum Tilt
January	6369	6817	7047
February	7140	7788	7457
March	7437	7168	7453
April	6909	7078	7075
May	6220	6680	6783
June	5453	5998	6082
July	5027	5410	5438
August	5421	5688	5625
September	5729	6046	5743
October	5331	5367	5413
November	5329	5160	5703
December	5542	5818	6191

Table 4: Total Irradiation on the Tilted Surface

3. OPTIMUM TILT ANGLE OF SOLAR PANEL

To get the most from solar panels, you need to point them in the direction that captures the most sun. But there are a number of variables in figuring out the best direction. This page is designed to help find the best placement of solar panels in any situation. This advice applies to any type of panel that gets energy from the sun; photovoltaic, solar hot water, etc. We assume that the panel is fixed, or has a tilt that can be adjusted seasonally. Panels that track the movement of the sun throughout the day can receive 10% (in winter) to 40% (in summer) more energy than fixed panels.

Solar panels should always face true south if you are in the northern hemisphere, or true north if you are in the southern hemisphere. True north is not the same as magnetic north. If compass is used to orient the panels, “magnetic declination” should be used to correct the difference, which varies from place to place.

The next question is, at what angle from horizontal should the panels be tilted? Books and articles on solar energy often give the advice that the tilt should be equal to your latitude, plus 15 degrees in winter or minus 15 degrees in summer. It turns out that you can do better than this about 4% better.

3.1 FIXED OR ADJUSTABLE

The mounts of solar panels now a days are provided with greater flexibility i.e. one can keep them fixed to latitude angle or can tilt them to adjust until optimum angle as per sun’s intensity based on seasons. For instance when tilts are adjusted to and fro seasonally at 40° latitude for a panel, the conversion gains are quite desirable as depicted in the below table and the graph is shown for different adjustability; annually.

Tilt Adjustment	Fixed	Adj.2 seasons	Adj.4 seasons	2-axis tracker
Percent Gain of optimum energy	71.1%	75.2%	75.7%	100%

Color of line (in graph) indicating energy gain per day for yearly adjustability.	Turquoise, Violet (winter angle)	-	Red	Green

Table 5: Tilt Adjustment

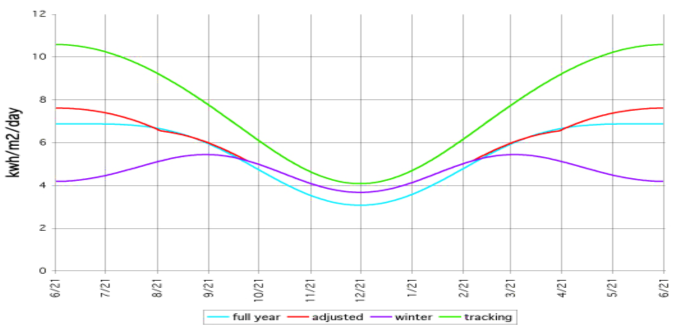

Figure 3: Solar Radiation Graph

The formula below finds the best angle from the horizontal at which the panel should be tilted and with the help of the table:

*Optimal Tilt = (Latitude Angle in degrees * multiplication factor) + Additional degrees*

Latitude Angle	Multiplication factor	Additional Degrees
Below 25 °	0.87	0
Between 25° and 50°	0.76	3.1
Above 50°		

Table 6: Multiplication factors for calculation of optimal Tilt angle with different latitude angles

3.2 ADJUSTING THE TILT TWICE A YEAR

The following table gives the best dates on which to adjust the panel tilt twice a year:

	Northern hemisphere	Southern hemisphere	Optimal tilt if Latitude Angle is between 25° and 50°
Adjust to summer angle on	March 30	September 29	(Lat*0.93)-21°
Adjust to winter angle on	September 12	March 14	(Lat*0.875)+19.2°

Table 7: Best dates to adjust the Tilt two times a year

3.3 ADJUSTING THE TILT FOUR TIMES A YEAR

The following table gives the best dates on which to adjust the panel tilt four times a year. This is advantageous to Grid tied systems.

In winter, a panel fixed at the winter angle will be relatively efficient, capturing 81 to 88 percent of the energy compared to optimum tracking. In the spring, summer, and autumn, the efficiency is lower (74-75% in spring/autumn, and 68-74% in summer), because in these seasons the sun travels a larger area of the sky, and a fixed panel can't capture as much of it. These are the seasons in which tracking systems give the most benefit.

Note that the winter angle is about 5° steeper than what has been commonly recommended. The reason is that in the winter, most of the solar energy comes at midday, so the panel should be pointed almost directly at the sun at noon. The angle is fine-tuned to gather the most total energy throughout the day.

The summer angles are about 12 degrees flatter than is usually recommended. In fact, at 25° latitude in summer, the panel should actually be tilted slightly away from the equator.

	Northern hemisphere	Southern hemisphere	Optimal tilt if Latitude Angle is between 25° and 50°
Adjust to summer angle on	April 18	October 18	(Lat*0.92)-24.3°
Adjust to autumn angle on	August 24	February 23	(Lat*0.98)-2.3°
Adjust to winter angle on	October 7	April 8	(Lat*0.89)+24°
Adjust to spring angle on	March 5	September 4	(Lat*0.98)-2.3°

Table 8: Best dates to adjust the Tilt four times a year.

4. MATLAB CODING

An optimal tilt angle essentially can be calculated by using MATLAB which provides quick and correct results. When the necessary inputs are provided to the matlab code, gives out the respective tilt to the relevant data at location of interest. This saves lot of time and complex math calculations which are to be done manually otherwise. Also this code provides greater flexibility in finding optimum tilt instantly for any number of sites by simply changing the inputs and executing the code. The code with comments given below is easy to grasp MATLAB code to obtain optimal tilt of solar panel on any day of a year and at any location on the planet blue.

```
Clear all;
clc;
ch=menu('choose a type of tilt
angle','monthly','seasonal','annual');
if(ch==1)
clc;
clearall;
day=input('\n day=');
%insert the sequence of the day in the month, from 1 to 31
x=input('\n month=');%insert the corresponding number
of the month, from 1 to 12
hour=input('\n hour=');%insert the hour in the 24 hour
system(e.g. 13 for 1 p.m)
min=input('minute=');%insert the minute,from 0 to 59
N=input('\n number of days in given month=');
L=input('local latitude in deg=');
Az=input('surface azimuth angle in deg=');%the values
above is local and independent.
Hg=input('monthly mean daily global radiation on
horizontal surface=');
HD=input('monthly mean daily diffuse radiation on
horizontal surface=');
Ro=0.2;%ground albedo
%%calculation of day sequence
m=[0 31 59 90 120 151 181 212 243 273 304 334];
n=m(x)+day;%this step evaluate the day sequence
number in the year
fprintf('\n day number:%d',n);
%%calculate of declination angle
x1=(360/365)*(284+n);
d=(23.45*sind(x1));%see equ(1)
fprintf('\n declination angle:%d',d);
%%calculation of houe angle
x2=hour+(min/60)-12;
h=x2*15;%see equ(2)
fprintf('\nhour angle:%d',h);
%%calculation of sun set hour angle
Hs=acosd(-tand(L)*tand(d));%sunset hour angle in
degrees
fprintf('\n sunsethour angle:%d',Hs);
hs1=acos(-tand(L)*tand(d));%sunset hour angle in
radians
fprintf('\n sunsethour angle:%d',hs1);
%%calculation of altitude angle
a=asind(sind(L)*sind(d)+cosd(L)*cosd(d)*cosd(h));%see
equ(3)
fprintf('\n altitude angle:%d',a);
%%calculation of zenith angle
Zs=90-a;
fprintf('\n solar zenith angle:%d',Zs);
%%calculation of day optimum tilt angle
Bt=atand(((sind(L)*cosd(d)*cosd(Az)*cosd(h))-
(cosd(L)*sind(d)*cosd(Az))+(cosd(d)*sind(Az)*sin(h)))/c
osd(Zs));
fprintf('\ndayoptimum tilt angle:%d',Bt);
%%calculation of direct beam radiation
Rb=((cosd(L-Bt)*cosd(d)*sind(Hs))+(hs1*sind(L-
Bt)*sind(d)))/((cosd(L)*cosd(d)*sind(Hs))+(hs1*sind(L)*
sind(d)));
Rb=abs(Rb);
fprintf('\n\n RB:%d',Rb);
HB=(Hg-HD)*Rb;%direct beam radiation
fprintf('\n\n direct beam radiation:%d',HB);

%%calculation of extra teristrial radiation
io=1373*(1+0.033*cosd(360*n)/365.25);
Ho=((N/pi)*(86400*io*cosd(L)*cosd(d)*(sind(Hs)-
(Hs*cosd(Hs)))));
fprintf('\n extra teristrial radiation:%d',Ho);
%%calculation of ground reflection beam radiation
HR=Hg*Ro*(1-cosd(Bt))/2;
fprintf('\n\n ground reflection beam radiation:%d',HR);
%%calculation of diffused beam radiation
Rd=((HB/Ho)*Rb)+(1-
(HB/Ho))*((1+cosd(Bt))/2)*(1+(sqrt(HB/Hg)*sind(Bt/2^
3)));
fprintf('\n\n rd:%d',Rd);
HD=Rd*HD;
fprintf('\n\n sky diffuse radiation:%d',HD);
%%calculation of total radiation on tilted surface
HT=HB+HR+HD;
fprintf('\n\n total radiation tilt surface:%d',HT);
elseif(ch==2)
clc;
clearall;
di=input('\n day sequence from month1=');%insert the
sequence of the day
inthemonth,from1to31
D2=input('\n day  sequence from month2=');%insert the
sequence of the day
inthemonth,from32to60
D3=input('\n day  sequence from month3=');%insert the
sequence of the day
inthemonth,from335to365
L=input('local latitude in deg=10.82');
Az=input('surface azimuth angle in deg=36.79');%the
values above is local and independent.
%%calculation of average declinatiion angle
D1=23.45*sind(284+D1)*(360/365);
fprintf('\n declination for month1:%d',D1);
D2=23.45*sind(284+D2)*(360/365);
fprintf('\n declination for month2:%d',D2);
D3=23.45*sind(284+D3)*(360/365);
fprintf('\n declination for month3:%d',D3);
D=(D1+D2+D3)/3;
fprintf('\n average seasonal declination angle:%d',D);
```

```
day=input('\n day=');%insert the sequence of the dayin the month,from 1 to 31
x=input('\n month=');insert thecorrespondingnumberofthemonth,from1to12
hour=input('\n hour=');% insert the hour in the 24 hour system (e.g. 13 for 1 p.m.)
min=input('minute=');%insert the minute ,from 0 to 59
Hg=input('monthly mean daily global radiation on horizontal surface=');
HD=input('monthly mean daily diffuse radiation on horizontal surface=');
Ro=0.2;
%%calculation of day sequence
m=[0 31 59 90 120 151 181 212 243 273 304 334];
N=m(x)+day;%this step evaluate the day sequence number of the year
fprintf('\nday number:%d',N);
%%calculation of hour angle
x2=hour+(min/60)-12;
h=x2*15;%see equ(2)
fprintf('\nhour angle:%d',h);

%%calculation of altitude angle
a=asind(sin(L)*sind(D)+cosd(L)*cosd(h));%see equ(3)
fprintf('\n altitude angle:%d',a);
%%calculation of zenith angle
Zs=90-a;
fprintf('\n solar zenith angle:%d',Zs);
%%calculation of seasonal tilt angle
Bt=atand(((sind(L)*cosd(D)*cosd(Az)*cosd(h))-(cosd(L)*sind(D)*cosd(Az))+(cosd(D)*sind(h)))/cosd(Zs));
fprintf('\n average seasonal tilt angle:%d',Bt);
%%calculation of sun set hour angle
Hs=acosd(-tand(L)*tand(D));
fprintf('\n sunsethour angle:%d',Hs);
hs1=acos(-tand(L)*tand(D));%sunset hour angle in radians
fprintf('\n sunsethour angle:%d',hs1);
%%calculation of direct beam radiation
Rb=((cosd(L-Bt)*cosd(D)*sind(Hs))+(hs1*sind(L-Bt)*sind(D)))/((cosd(L)*cosd(D)*sind(Hs))+(hs1*sind(L)*sind(D)));
Rb=abs(Rb);
fprintf('\n\n rb:%d',Rb);
HB=(Hg-HD)*Rb;%direct beam radiation
fprintf('\n\n direct beam radiation:%d',HB);
%%calculation of ground reflection beam radiation
HR=Hg*Ro*(1-cosd(Bt))/2;
fprintf('\n\n ground reflection beam radiation:%d',HR);
%%calculation of diffused beam radiation
Rd=(1+cosd(Bt))/2;
fprintf('\n\n rd:%d',Rd);
HD=Rd*HD;
fprintf('\n\n sky diffuse radiation:%d',HD);
%%calculation of total radiation on tilted surface
HT=HB+HR+HD;
fprintf('\n\n total radiation tilt surface:%d',HT);
ELSE if(ch==3)
clearall;
clc;
day=input('\n Day=');%insert the sequence of the day in the month,from 1 to 31
x=input('\n Month=');%insert the corresponding number of the month,from 1 to 12
hour=input('\n Hour=');%insert the hour in the 24 hour system(e.g.13 for 1 p.m.)
min=input('minute=');%insert the minute from 0 to 59
L=input('\n local latitude in deg=');
Hg=input('monthly mean daily global radiation on horizontal surface=');
Hd=input('monthly mean daily diffuse radiation on horizontal surface=');
Ro=0.2;
%%calculation of day sequence
m=[0 31 59 90 120 151 181 212 243 273 304 334];
N=m(x)+day;%this step evaluate the day sequence number in the year
fprintf('\nday number:%d',N);
%%calculate of declination angle
x1=(360/365)*(284+N);
D=(23.45*sind(x1));%see equ(1)
fprintf('\n declination angle:%d',D);
%%calculation of hour angle

x2=hour+(min/60)-12;
h=x2*15;%see equ(2)
fprintf('\nhour angle:%d',h);
%%calculation of altitude angle
a=asind(sin(L)*sind(D)+cosd(L)*cosd(D)*cosd(h));%see equ(3)
fprintf('\n altitude angle:%d',a);
%%calculation of zenith angle
Zs=90-a;
fprintf('\n solar zenith angle:%d',Zs);
%%calculation of seasonal tilt angle
Bt=atand(((sind(L)*cosd(D)*cosd(Az)*cosd(h))-(cosd(L)*sind(D)*cosd(Az))+(cosd(D)*sind(Az)*sind(h)))/cosd(Zs));
fprintf('\n average seasonal tilt angle:%d',Bt);
%%calculation of sun set hour angle
Hs=acosd(-tand(L)*tand(D));
fprintf('\n sunsethour angle:%d',Hs);
hs1=acos(-tand(L)*tand(D));%sunset hour angle in radians
fprintf('\n sunsethour angle:%d',hs1);
%%calculation of direct beam radiation
Rb=((cosd(L-Bt)*cosd(D)*sind(Hs))+(hs1*sind(L-Bt)*sind(D)))/((cosd(L)*cosd(D)*sind(Hs))+(hs1*sind(L)*sind(D)));
```

```
Rb=abs(Rb);
fprintf('\n\n RB:%d',RB);
HB=(Hg-Hd)*Rb;%direct beam radiation
fprintf('\n\n direct beam radiation:%d',HB);
%%calculation of ground reflection beam radiation
HR=Hg*Ro*(1-cosd(Bt))/2;
fprintf('\n\n ground reflection beam radiation:%d',HR);
%%calculation of diffused beam radiation
Rd=(1+cosd(Bt))/2;
fprintf('\n\n Rd:%d',Rd);
HD=Rd*HD;
fprintf('\n\n sky diffuse radiation:%d',HD);
%%calculation of total radiation on tilted surface
HT=HB+HR+HD;
fprintf('\n\n total radiation tilt surface:%d',HT);
Else if(ch==3)
clearall;
clc;
day=input('\n Day=');%insert the sequence of the day in the month,from 1 to 31
x=input('\n Month=');%insert the corresponding number of the month,from 1 to 12
hour=input('\n Hour=');%insert the hour in the 24 hour system(e.g.13 for 1 p.m.)
min=input('Minute=');%insert the minute from 0 to 59
L=input('\n local latitude in deg=');
Hg=input('monthly mean daily global radiation on horizontal surface=');
Hd=input('monthly mean daily diffuse radiation on horizontal surface=');
Ro=0.2;
%%calculation of day sequence
m=[0 31 59 90 120 151 181 212 243 273 304 334];
N=m(x)+day;%this step evaluate the day sequence number in the year
fprintf('\nday number:%d',N);


%%calculate of declination angle
x1=(360/365)*(284+N);
D=(23.45*sind(x1));%see equ(1)
fprintf('\n declination angle:%d',D);
%%calculation of hour angle
x2=hour+(min/60)-12;
h=x2*15;%see equ(2)
fprintf('\nhour angle:%d',h);

%%calculation of altitude angle
a=asind(sin(L)*sind(D)+cosd(L)*cosd(D)*cosd(h));%see equ(3)
fprintf('\n altitude angle:%d',a);
%%calculation of zenith angle
Zs=90-a;
fprintf('\n solar zenith angle:%d',Zs);
%%calculation of seasonal tilt angle
Bt=L;
fprintf('\n average seasonal tilt angle:%d',Bt);
%%calculation of sun set hour angle
Hs=acosd(-tand(L+Bt)*tand(D));
fprintf('\n sun set hour angle:%d',Hs);
hs1=acos(-tand(L+Bt)*tand(D));%sunset hour angle in radians
fprintf('\n sun set hour angle:%d',hs1);
%%calculation of direct beam radiation
Rb=((cosd(L-Bt)*cosd(D)*sind(Hs))+(hs1*sind(L-Bt)*sind(D)))/((cosd(L)*cosd(D)*sind(Hs))+(hs1*sind(L)*sind(D)));
Rb=abs(Rb);
fprintf('\n\n rb:%d',RB);
HB=(Hg-Hd)*RB;%direct beam radiation
fprintf('\n\n direct beam radiation:%d',HB);
%%calculation of ground reflection beam radiation
HR=Hg*Ro*(1-cosd(Bt))/2;
fprintf('\n\n ground reflection beam radiation:%d',HR);
%%calculation of diffused beam radiation
Rd=(1+cosd(Bt))/2;
fprintf('\n\n Rd:%d',Rd);
HD=Rd*HD;
fprintf('\n\n sky diffuse radiation:%d',HD);
%%calculation of total radiation on tilted surface
HT=HB+HR+HD;
fprintf('\n\n total radiation tilt surface:%d',HT);
end;
end;
```

5. RESULTS AND DISCUSSION

Represented tilt angle for month, seasonal and year wise the seasonal average is calculated by taking average of tilt angle for each season and same is implemented 4times a year. in winter the angle of collector should be 33° during spacing tilt is 5.4° in summer tilt is 5°and during autumn tilt is 23° the yearly average tilt is calculation by taking average of all months or it also can be maintained at latitude angle which 14°.neagive tilt angle incidences that the solar panel towards north during summer in order to capture maximum solar irradiation the orientation of solar collector also plays an important role as tilt angle of collector which gives a loss of 1.1% if fix panel toward role as tilt angle of increased /decreased loss according to location .

	Yearly tilt average solar irradiation /hr(w/m2)	Seasonal tilt average solar irradiation (w/m2)	Monthly tilt. Average solar irradiation/hr (w/m2)
January	909	973	1006
February	1020	1112	1065
March	1062	1023	1064
April	987	1011	1010
May	888	954	969
June	779	856	868
July	718	772	776
August	774	812	803
September	818	863	820
October	761	776	713
November	761	737	814
December	791	807	884

Table 9: Average Irradiation Per Hour By Maintaining Monthly ,Seasonal And Yearly Optimum Tilt Angles.

Month	Yearly optimum tilt average hourly Irradiation (w/m2)	Power(w/h)	Number of kwh/month
January	909	893	194
February	1020	999	195
March	1062	1046	227
April	987	969	203
May	888	873	189
June	779	764	160
July	718	703	152
August	774	759	164
September	818	802	168
October	761	746	161
November	761	746	156
December	791	775	168
Total Kwh		2193	

Table 10: Yearly Optimum Tilt Average Hourly Irradiation

Month	Seasonal optimum tilt average hourly Irradiation (w/m2)	Power(w/h)	Number of kwh/month
January	973	954	207
February	1112	1095	214
March	1023	1002	217
April	1011	990	203
May	954	9.6	176
June	856	839	164
July	772	757	172
August	812	795	177
September	863	843	165
October	776	761	151
November	737	720	172
December	807	791	165
Total Kwh		2226	

Table 11: Seasonal Optimum Tilt Angle Irradiation

The average hourly irradiation during January using monthly optimum tilt is 1006w/m2 which is given as input to simulation per irradiation G by simulating the solar set up the power obtained is 986w/m. Number of kwh generated per month is 0.986kw/h 31days =213wh/month

By maintaining monthly and seasonal optimum tilt angle the solar setup achieve 5.6 and 4.6 percent more energy compared with the yearly field system.

Month	Monthly optimum tilt average hourly irradiation (w/m2)	Power(w/h)	Number of kwh/month
January	1006	996	213
February	1065	1049	205
March	1064	1048	227
April	1010	990	207
May	969	951	206
June	868	850	178
July	776	761	165
August	803	787	170
September	820	802	168
October	713	698	150
November	814	797	169
December	884	861	180

Table 12: Number of Kwh/Month With Only Optimum Tilt Angles

Month	Annual tilt kwh/month	Seasonal With kwh/month	Monthly Tilt kwh/month
January	194	213	220
February	195	22	212
March	227	224	234
April	203	214	214
May	189	208	212
June	160	180	182
July	152	167	168
August	164	176	174
September	168	181	172
October	161	168	153
November	156	153	171
December	168	175	193
Total	2137	2281	2305

Table 13: Annual, Seasonal and Monthly Tilt Kwh/Month

Number of kwh generated by 1km solar system using optimum tilt angle. The number of kwh/month achieved using monthly, seasonal and fixed optimum tilt angles. For a 1kw system fixed/yearly optimum tilt we can achieve 213kwh/month at the same way by seasonal optimum tilt angle we can achieve 228 kw/month with optimum tilt.

6. CONCLUSION & FUTURE SCOPE

Using relevant meteorological parameters and the methods described in this study, monthly averages of the beam irradiation, the diffused radiation and the global irradiation at different tilt angles was determined. The effects and contributions of each of the components (beam, diffuse) for the general case and at their optimum angles were highlighted. Result from the study shows that, using the tilt angle that yields the optimum irradiation for each month can substantially increase PV energy production.

The average annual maximum irradiation could be obtained at a tilt angle of about 6° which is approximately equal to the latitude of the location. The results obtained could be used to estimate the KWh generation of a PV module at any site of interest.

Design and develop the plug and play solar rooftop power system. This work mainly focuses on three areas of optimization. Module spacing and tilt azimuth orientation, inverter and power optimizer with shade tolerance.

REFERENCES:

[1] A. Keyhani, Design of Smart Power Grid Renewable Energy Systems . John Wiley & Sons, Inc., New Jersey,2011.

[2] Y. Udoakah, and M. Umoh, "Sustainably Meeting the Energy Needs of Nigeria: The Renewable Options," In: Proceedings of the IEEE International Energy Conference (ENERGYCON) pp. 326-332, 2014.

[3] I. Bugaje, "Renewable energy for sustainable development in Africa: a review, "Renewable and Sustainable Energy Reviews , vol. 10, no. 6, pp. 603–612, 2006.

[4] C. Augustine, and M. Nnabuchi, "Relationship between global solar radiation and sunshine hours for Calabar, Port Harcourt and Enugu, Nigeria," International Journal of Physical Sciences, vol. 4, no.4, pp. 182–188, 2009.

[5] A. El-Sebaii, F. Al-Hazmi, A. Al-Ghamdi, and S. Yaghmour, "Global, direct and diffuse solar radiationon horizontal and tilted surfaces in Jeddah, SaudiArabia," Applied Energy, vol. 87, pp. 568–576, 2010.

[6] M. Ahmad, and G. Tiwari, "Optimization of Tilt Angle for Solar Collector to Receive Maximum Radiation,"The Open Renewable Energy Journal , vol.2, pp. 19-24, 2009.

[7] M. Hanif, M. Ramzan, M. Rahman, M. Khan, M. Amin, and M. Aamir, "Studying Power Output of PV Solar Panels at Different Temperatures and Tilt Angles," ISESCO Journal of Science and Technology , Vol. 8, No. 14, pp. 9-12, 2012.

[8] E. Taymur, Photovoltaic System Sizing [thesis]. Columbs: The Ohio State University, 2009.

[9] U. Akpan, and M. Umoh, "Horizontal Global Solar Radiation Based on Sunshine Hours Over Enugu, Nigeria" Canadian Journal of Pure & Applied Sciences , Vol. 5, No. 2, pp. 1553-1557, 2011.

[10] T. Markvart, and L. Castaner, Practical handbook of photovoltaics fundamentals and applications. Amsterdam: Elsevier, 2003.