



Effect of Tilt angle and Azimuth angle on Solar Output and Optimum Tilt and Azimuth angle for Chandigarh, India

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ABSTRACT: Solar Power is gaining more interest all over the world these days because of its various advantages. But at the same time efficiency of the plant is an important factor to consider. At any given location represented by its latitude and longitude the solar output is affected by tilt angle and azimuth angle. These angles play an important role in the efficiency of the solar plant. In this paper, the effect of tilt angle and azimuth angle on solar output has been calculated & is given. The analysis is done using Helioscope software. The optimum values of tilt angle and azimuth angle for Chandigarh location have thus been found.

KEYWORDS:SPV (Solar Photovoltaic), PV (Photovoltaic).

I.INTRODUCTION

With the day by day advancement in technology, the energy consumption and energy requirement has increased manifold which can never be fulfilled by the centralized generation from fossil fuels. Thus, the countries all over the world are promoting power generation from renewables. Out of renewables, the solar power attracts huge interest because of its salient features like it supports distributed generation, needs minimum maintenance, payback period is small etc. In any power generation plant, the major and important issue is to improve the efficiency of the plant. In solar power plant, the tilt angle and azimuth angle play important role towards the efficiency of the plant. Thus, it is very important to orient the solar panels at tilt angle and azimuth angle for any given location.

Tilt angle of the photovoltaic (PV) array is the key to yield an optimum energy output. Solar panels or PV arrays are most efficient, when they are perpendicular to the sun's rays [1] [2] [3]. However, throughout the year the sun's path and the solar altitude vary. In summers, sun is high in the sky whereas in winters it is lower shown in fig 1.

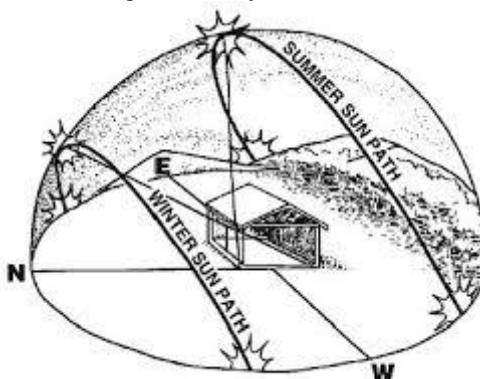


Fig. 1 Sun's path during summers and winters.

The default value of tilt angle is equal to the station's latitude plus 15 degrees in winter or minus 15 degrees in summer. This normally maximizes annual energy production. Increasing the tilt angle favours energy production in the winter, while decreasing the tilt angle favours energy production in the summer. The tilt angle of PV panel is given in fig 2.

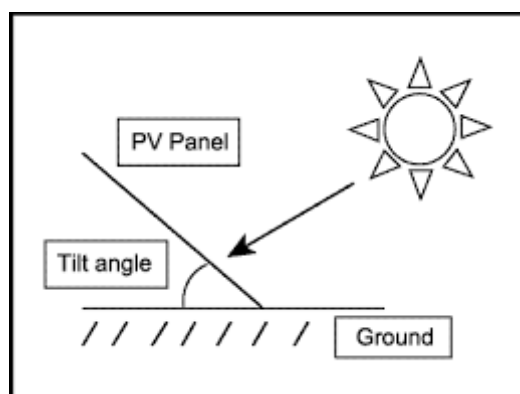


Fig. 2 Tilt angle of PV panel.

Solar azimuth angle is the azimuth angle of the sun; it defines the direction the sun is in [4] [5] [6]. The most commonly accepted convention for analysing solar irradiation, e.g. for solar energy applications, is clockwise from due North, thus East is 90° , South is 180° and West is 270° which is shown in fig 3.

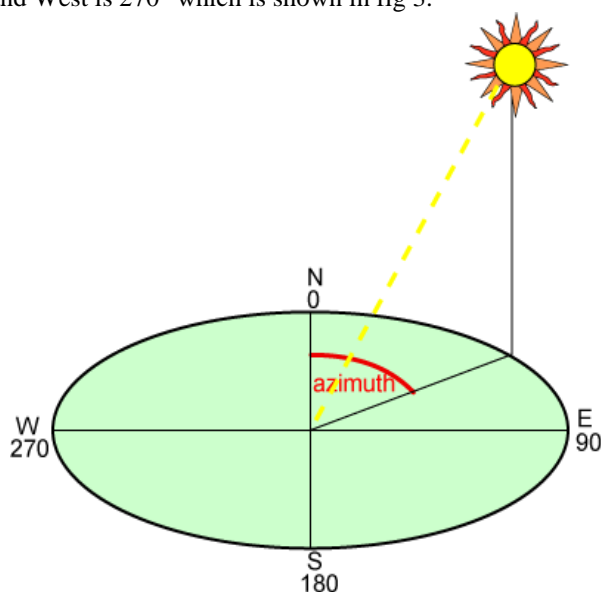


Fig. 3 Azimuth angle of solar panel/array.

The tilt angle and azimuth angle are month as well as location dependent, i.e., every location will have different tilt and azimuth angles for different months of a year.

II. HELIOSCOPE SOFTWARE

Helioscope is the web application designed by Folsom Labs, California in United States. Helioscope does what both PVSyst and AutoCAD do together [8]. Helioscope is big time saviour for energy modelling because it provides automation [9].

The key benefits of Helioscope are as follows:

- Quickly evaluate potential sites.
- Analyse design decisions.
- Simplify the workflow.

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To use Helioscope, there are four steps:

- 1) Create Project
- 2) Create Design
 - i. Create Design (Mechanical)
 - ii. Create Design (Electrical)
- 3) Create Condition Set
- 4) Run Simulation and View Report

III.METHODOLOGY

The methodology to find out optimum tilt angle and azimuth angle is given in fig 4 and 5 respectively.

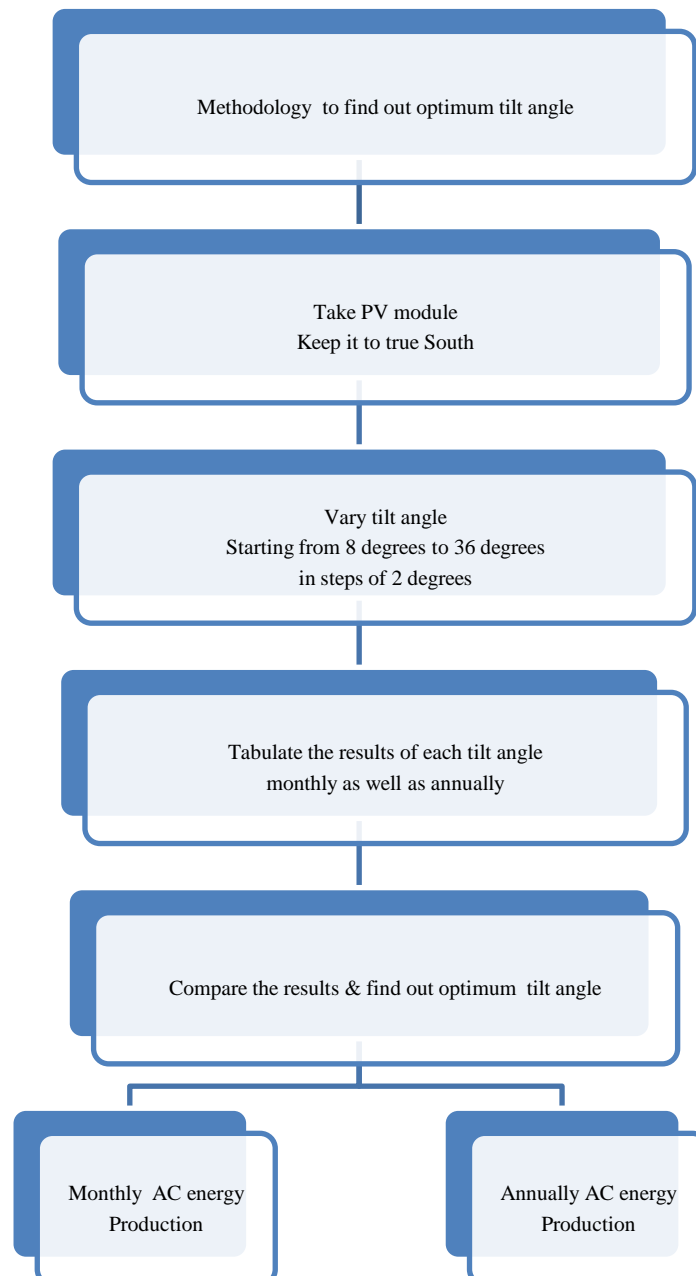


Fig. 4 Methodology to find out optimum tilt angle.

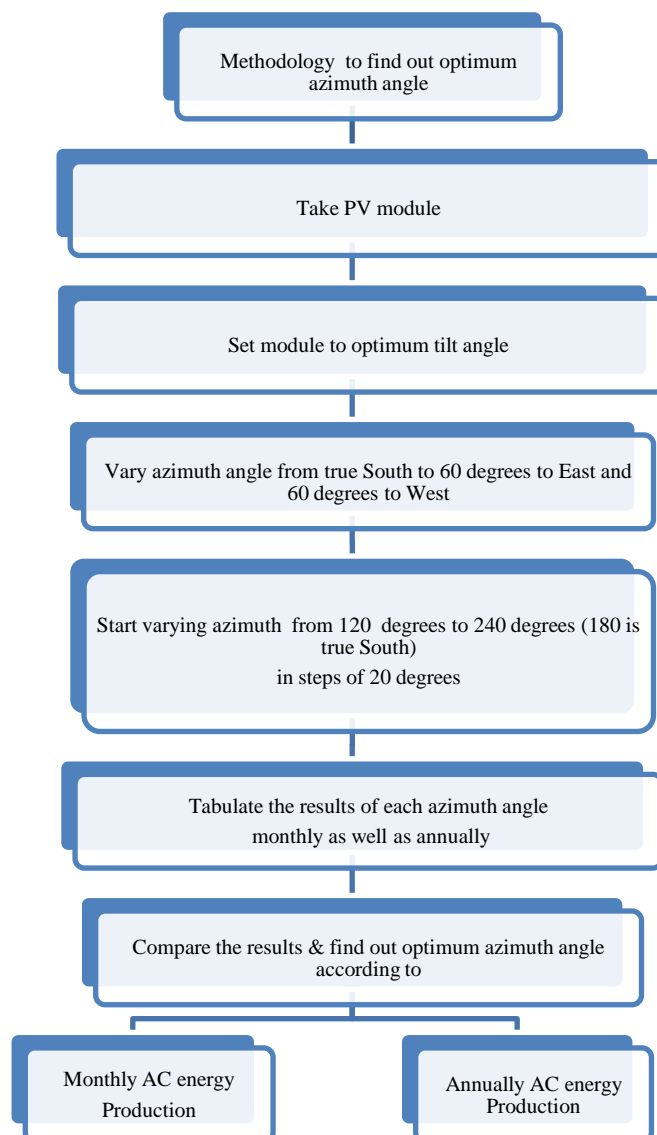


Fig. 5 Methodology to find out optimum azimuth angle.

IV. ANALYSIS AND RESULTS

In the analysis, Electrical Department of PEC University of Technology, Chandigarh is used as location. First of all, the project name and its address are provided then the software automatically takes up the longitude and latitude. Chandigarh's longitude is 76.7783748 degrees and latitude is 30.766192 degrees. PV module used for the analysis is of polycrystalline technology made up of silicon.

Study of effect of tilt angle on solar PV output

In the analysis, the tilt angle is varied from 8 degrees to 36 degrees in steps of 2 degrees. At different tilt angles, the solar output is noted down and the effect of tilt angle is compared.

The mechanical design is created by selecting the area in which SPV plant is to be installed. Then following inputs are provided:

- i. PV module of 240Wp,
- ii. Azimuth angle = 180 degree which is true South,
- iii. Tilt angle varies between 8 degrees to 36 degrees in steps of 2 degrees,
- iv. Horizontal (landscape) orientation,



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- v. Fixed tilt racking,
- vi. Row spacing = 2 feet,
- vii. Module spacing = 0.032 feet,
- viii. Setback = 4 feet,

In the electrical design, the following inputs are provided:

- i. PVS800-57-0100kW-A Inverter,
- ii. Combiner poles = 12,
- iii. String length = 22,
- iv. Stringing along racking.

Then the weather condition set is provided and then design is simulated. The solar output at various tilt angles in each month (kWh) of the year as well as annual AC energy production (MWh) is given in table 1.

Table 1
AC Energy Generated at Various Tilt Angles Monthly and Annual

Tilt	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°	32°	34°	36°
Jan (kWh)	2,277.4	2,341.1	2,403.5	2,457.9	2,508.5	2,551.1	2,590.3	2,616.7	2,635.4	2,641.7	2,619.4	2,584.1	2,528.8	2,466.7	2,403.4
Feb (kWh)	2,700.4	2,760.5	2,815.9	2,867.9	2,914.5	2,956.1	2,992.3	3,021.2	3,044.7	3,069.5	3,078.3	3,087.3	3,084.1	3,070.4	3,042.9
March (kWh)	3,535.7	3,582.4	3,622.3	3,655.0	3,686.5	3,707.9	3,725.9	3,736.1	3,740.9	3,746.8	3,736.9	3,734.3	3,718.4	3,698.5	3,673.0
April (kWh)	3,846.1	3,861.7	3,873.7	3,880.2	3,882.7	3,876.2	3,865.0	3,847.3	3,822.1	3,797.3	3,761.9	3,726.6	3,682.0	3,633.8	3,579.6
May (kWh)	3,923.6	3,915.8	3,902.5	3,878.9	3,855.6	3,826.1	3,786.3	3,741.9	3,692.5	3,641.8	3,578.9	3,519.2	3,449.4	3,376.4	3,299.4
June (kWh)	3,529.0	3,513.7	3,492.2	3,464.7	3,436.5	3,398.7	3,356.2	3,308.7	3,256.1	3,203.0	3,137.2	3,078.3	3,008.6	2,936.0	2,859.9
July (kWh)	3,140.8	3,130.2	3,118.0	3,095.7	3,072.6	3,044.3	3,009.9	2,968.7	2,926.1	2,880.6	2,830.4	2,777.4	2,718.0	2,656.2	2,591.0
Aug (kWh)	3,225.7	3,229.9	3,230.2	3,221.5	3,213.8	3,197.7	3,172.9	3,147.1	3,114.4	3,081.5	3,038.7	3,000.9	2,951.6	2,899.6	2,843.6
Sept (kWh)	3,246.2	3,275.7	3,299.9	3,317.2	3,332.7	3,341.7	3,343.1	3,341.1	3,333.6	3,322.7	3,303.7	3,285.5	3,258.6	3,228.3	3,193.7
Oct (kWh)	3,150.4	3,210.3	3,264.6	3,311.4	3,357.4	3,394.1	3,427.1	3,453.5	3,476.9	3,493.5	3,499.5	3,507.3	3,503.3	3,493.2	3,475.2
Nov (kWh)	2,607.8	2,684.3	2,757.0	2,822.1	2,885.2	2,941.7	2,989.0	3,024.7	3,056.2	3,076.0	3,074.4	3,062.2	3,020.5	2,965.0	2,897.9
Dec (kWh)	2,227.6	2,303.3	2,373.8	2,436.6	2,497.6	2,549.0	2,591.2	2,619.8	2,631.8	2,624.6	2,575.0	2,522.0	2,456.0	2,394.2	2,340.3
Annual Production (MWh)	37.41	37.81	38.15	38.41	38.64	38.78	38.85	38.83	38.73	38.58	38.23	37.89	37.38	36.82	36.20

Study of effect of azimuth angle on solar PV output

Azimuth angle is varied 60 degrees to east and west from true south in steps of 20 degrees. The solar output is noted down at different azimuth angle by freezing the tilt angle and thus the effect of azimuth angle is studied.

All the inputs in mechanical design and electrical design are same as before in study of tilt angle only the azimuth angle is varied between 120 degrees to 240 degrees where 180 degree is true south. The tilt angle is now freed to 20 degrees which is optimum tile angle for Chandigarh according to annual AC energy generated. Then following inputs are provided:

- i. PV module of 240Wp,
- ii. Azimuth angle = varied in between 120 degrees to 240 degrees in steps of 20 degrees,
- iii. Tilt angle = 20 degree,
- iv. Horizontal (landscape) orientation,
- v. Fixed tilt racking,



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- vi. Row spacing = 2 feet,
- vii. Module spacing = 0.032 feet,
- viii. Setback = 4 feet,

In the electrical design, the following inputs are provided:

- i. ABB, PVS800-57 -0100kW-A Inverter,
- ii. Combiner poles = 12,
- iii. String length = 22,
- iv. Stringing along racking.

The weather condition set is provided for Chandigarh and the design is simulated. The solar output (AC energy generated) monthly in kWh and annually in MWh for various azimuth angles is respectively given in table 2.

Table 2
AC Energy Generated at Various Azimuth Angles Monthly and Annual

Azimuth Angle	120°	140°	160°	180°	200°	220°	240°
Jan (kWh)	2,188.2	2,384.5	2,528.4	2,590.3	2,528.1	2,382.5	2,186.7
Feb (kWh)	2,621.7	2,807.5	2,940.2	2,992.3	2,930.0	2,781.4	2,584.3
March (kWh)	3,397.8	3,569.3	3,687.6	3,725.9	3,688.3	3,572.7	3,399.4
April (kWh)	3,694.5	3,792.9	3,850.9	3,865.0	3,834.4	3,759.8	3,649.7
May (kWh)	3,713.2	3,749.7	3,773.9	3,786.3	3,785.3	3,772.8	3,738.3
June (kWh)	3,340.4	3,351.5	3,355.0	3,356.2	3,355.9	3,354.6	3,345.3
July (kWh)	3,003.9	3,014.7	3,015.1	3,009.9	2,998.5	2,981.3	2,957.3
Aug (kWh)	3,084.5	3,139.8	3,168.5	3,172.9	3,161.9	3,125.0	3,059.5
Sept (kWh)	3,099.0	3,220.9	3,309.6	3,343.1	3,321.4	3,242.5	3,123.3
Oct (kWh)	3,026.4	3,229.5	3,371.5	3,427.1	3,375.4	3,231.8	3,038.9
Nov (kWh)	2,503.3	2,732.7	2,905.7	2,989.0	2,915.1	2,737.7	2,509.8
Dec (kWh)	2,150.4	2,364.9	2,522.9	2,591.2	2,515.5	2,349.9	2,131.9
Annual Energy Production (MWh)	35.82	37.36	38.43	38.85	38.41	37.29	35.72

VI.CONCLUSION

From Table 1, comparing annual AC energy generated at various tilt angles, it is noted that if there is fixed system, then 20 degree tilt angle is optimum for Chandigarh and if there is movable system, then the optimum tilt angle in each month is given in table 3.

From Table 2 comparing AC energy generated at various azimuth angles, it is noted that the AC energy generated is maximum when the azimuth angle is 180 degree i.e. the optimum azimuth angle for Chandigarh location is true south from North. The month-wise azimuth angle is given in table 3.

Table 3
Month-wise Tilt and azimuth Angle

Month	Tilt angle	Azimuth angle
Jan	26°	180°
Feb	30°	180°
March	26°	180°
April	16°	180°
May	8°	180°
June	8°	180°
July	8°	160°
Aug	12°	180°
Sept	20°	180°
Oct	30°	180°
Nov	26°	180°
Dec	24°	180°



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