PLC based Solar Panel Tracking System with Automatic Tilting Arrangement and Tilt Angle Optimization

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Abstract

Improving the conversion efficiency of solar panel has become a challenging area of study for researchers. Solar trackers are an alternative to reach this goal, by tracking the position of the sun changes, the productivity of the panel increases. The variation of the tilt angle changes solar radiation that reaches to the surface of the collector. Hence tilt angle is the important factor that affects the performance of a solar collector. This paper presents a new design of a Three-axis solar tracking system which is based on Programmable Logic Controller (PLC). The automatic tracking system of solar radiation is done on the basis of radiation tracking system. Consumption and efficiency of solar PV cell is compared with existing method. The optimization of the tilt angle of solar panel will maximize the power generation.

Keywords: *Solar panel, Three-axis tracker, optimization method, PLC.*

1. INTRODUCTION

The increasing energy dependence limited source of the fossil fuels, their increasing price and negative environmental impacts force mankind to improve the utilization of the available renewable energy sources. Renewable sources represent an inexhaustible potential of energy for the future. Among renewable sources solar energy is one of the most promising now days. The sun's position tracker mechanism is to be composed of the PLC, DC Motor, worm gear, photo sensor, encoder, power relay and inclinometer. The program to tilt the panel according to sun's position is to be feed on PLC. An inclinometer fixed behind the panel measure the angle of panel and it gives feedback to PLC.An overview of the solar cell technologies and their efficiency of this conversion depends on solar radiation that reaches the surface of the solar cell. Another option is to track the sun's path in daylight hours. Some researchers have conducted various studies to establish the optimal degree of tilt solar panel to increase the output power. Because the

position of the sun changes during the courses of the day the implementation of the solar tracker is the best solution to increase the energy production. The performance of a solar collector is highly influenced by its orientation (regarding the Equator) and its tilt angle (regarding the ground).this can be achieved by proper design, construction, installation and orientation. In PV cell shadows are known to damage the solar cell due to the creation of the hot spot to the panel. From the reference study it can be seen that optimization of tilt angle of the solar panel can be done by using Soft-Computing technique. Depending on number of axis the panel can be move and tracking can be differentiated. Knowledge of these angles would further allow us to track the sun on a monthly basis rather than daily hour based tracking. The process can be seen from the Fig 1.

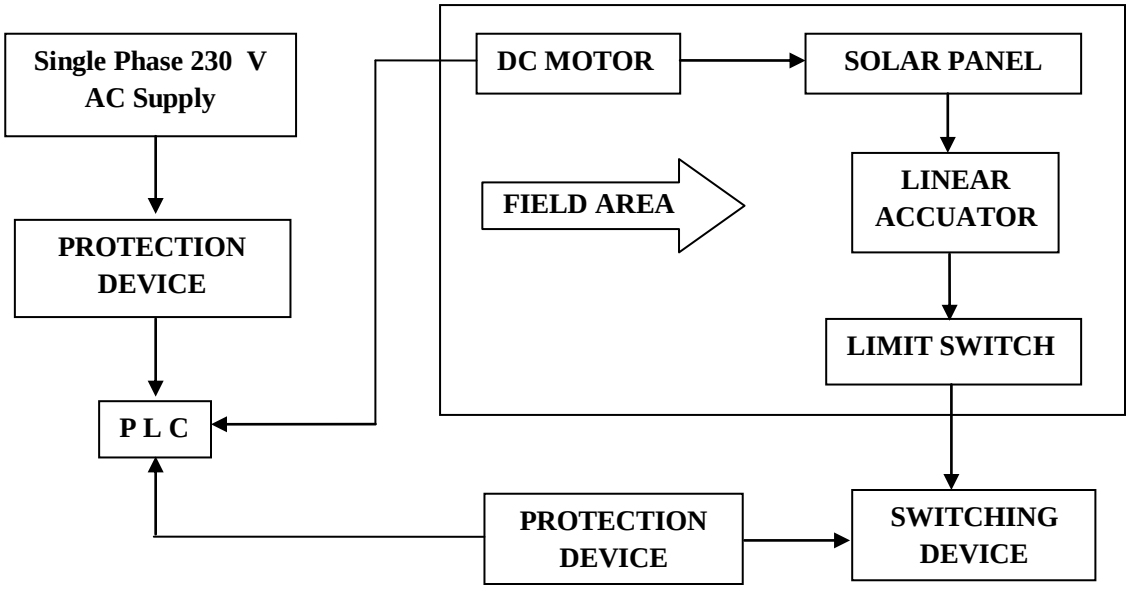

Fig.1 Block Diagram

1.1 Solar Angles

The solar radiation reaching area per square meter in the outer atmosphere is 1367 W/m². However, some of the sun lights falling on the earth are absorbed and reflected back by the atmosphere and the clouds. Some angles form between the sunlight falling on the earth and the surfaces. The position of the sun at different periods is determined by the solar angles. Moreover, solar angles are used to track the movement of the sun in a day. The rotation of the sun varies depending on the latitude and longitude of the location. Therefore, the solar angles will be different for the locations at different latitude and longitude during the same period. So, the solar angles must be known to determine the position of the sun. The various solar angles can be seen from Table 1.

S.No	ANGLES	SYMBOLS	FORMULA	DESCRIPTION
1.	Latitude	Ø	–	The angle forming according to the equator center.
2.	Declination	δ	$23.45 \sin[\, 360^0 \frac{(n-81)}{365}]$	The angle between the sun lights and equator plane.
3.	Hour	ω	$15(t_s - 12)$	The angle between the longitude of sun lights and the longitude of the location.
4.	Incident	θ	$\cos^{-1}(\delta)\cos(\emptyset)\cos(\omega) - \sin(\delta)\sin(\emptyset)$	The angle between the radiation falling on the surface directly and the normal of that surface.
5.	Elevation	α	$90 - \theta$	The angle between the line to the sun and the horizontal plane.
6.	Tilt	β	$\beta = \lvert\emptyset - \delta\rvert$	The angle between the panels and the Horizontal plane.

Table.1 Solar Angles

2. METHODOLOGY

With the help of above equations in the Table.1 we are able to calculate the other values for photo voltaic cell like horizontal radiation(S_h),module radiation(S_m),declination angle of the sun(δ),elevation angle of the sun(α) and tilt angle(β) for these values for each month of the year. Using pveducation.org website and for graphics design we use MS-Excel, month wise output graphs are drown by all insolation and angle of tilting. All formulas are compared after formulating by angle that is tilting for finding the optimum tilt angle with respect to maximum insolation.

For calculating the optimal tilt angle on mathematical analysis for Bhilai for January month to receive maximum output energy from the Solar panel, we use several procedures which are given bellow:

- Firstly we collect the data like incident solar energy for number of days of year having gap of four days because after every 4 days, the incident angle is changed, for Bhilai with its (Latitude=21.1938^0 N and Longitude=81.3509^0 E).
- These data is taken from the timeanddate.com website for Bhilai location January month. These data is about the sun's incident rays along with angles from rising to setting time. From these an Hour angle (ω) can be calculated with the help of solar time.
- After then we calculate the declination angle of the earth by Liu and Jordan model. By calculating the value of declination angle for about gap of four days of a month, calculation of elevation angle(α) are done with the help of equation no. 2 successfully.
- With the help of this elevation angle, two quantities are calculated that one is horizontal energy of the sun at the panel (S_h), and second is the module energy (S_m), which is falling on the panel and most important factor for the panel efficiency.
- For calculation of module energy by equation no. 1,we take the tilt angle(β) which we have taken data from timeanddate.com for January month and observe the different values of module energy for different tilt angle for Bhilai location.
- After that calculation, we find out and separate the optimum tilt angle for Bhilai location for January month at which solar panel will receive maximum output energy for use.

2.1 Formula used

Module Radiation is as:

$$S_{module} = S_{incident} * \sin(\alpha + \beta) \quad (1)$$

Where;
α is the angle of elevation of the sun;

β is the angle at which panel is tilted and calculate from ground

The elevation angle is as:

$$\alpha = 90 - \theta \quad (2)$$

Where;

θ is the incident angle of the sun

The Declination angle is:

$$\delta = 23.45 \sin[\, 360^0 \tfrac{(n-81)}{365}] \quad (3)$$

Where n is no. of day from year. For simplification of calculation, we take (284+n) =(n-81).

These equ. gives the link among S_{module} and $S_{horizontal}$ can be calculated as:

$$S_{module} = \frac{S_{horizontal}}{\sin \alpha} * \sin(\alpha + \beta) \quad (4)$$

2.1.1 Calculated Value of Tilt Angle with Module energy for January Month

Number of days having tilt angle at which max module energy is shown in Table 2 along with graphical view in Fig.2:

Number of days (n)	Tilt Angle (degree)	Module Energy(kwh/m²/day)
1	45	8.29
4	43	8.57
8	41	8.73
12	39	9
16	37	9.15
20	35	9.71

Table.2 Tilt angle & module energy for the no. of day of January month

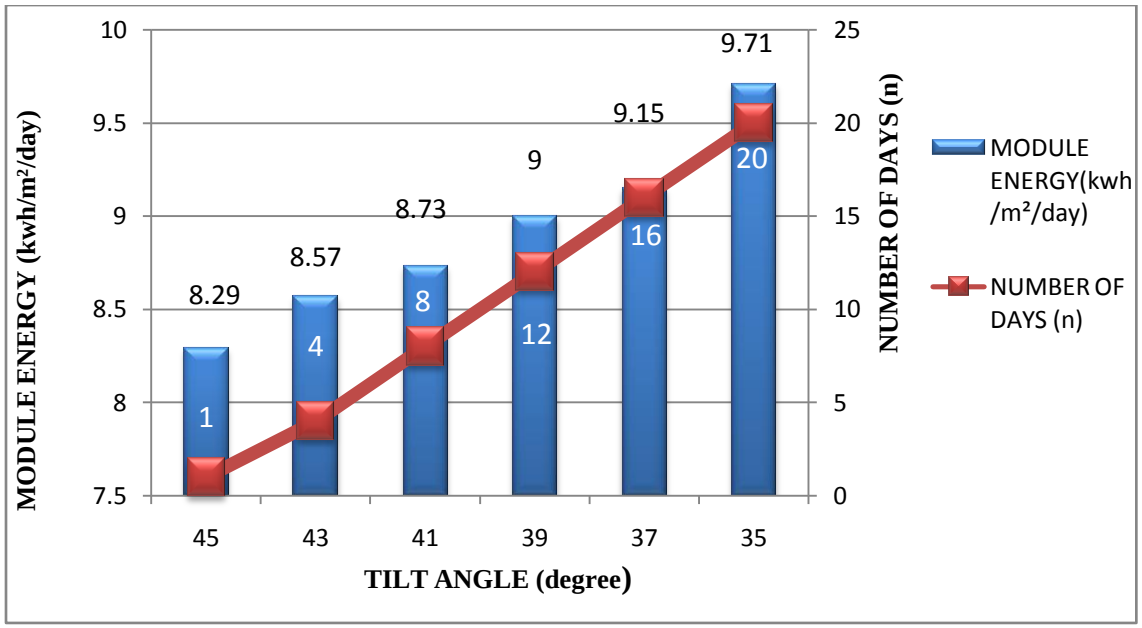

Fig.2 Optimum tilt angle, maximum module energy with number of days for January

These data are generally based on mathematical analysis which is represented in the tabular and graphical form.

2.2 Experimental setup

The designed tracking system consists of a software based tracking method as shown in Fig 3.The main components of the designed system consist of Three-axis movement solar panel which contain light dependent resistors (LDR) as sun sensors, programmable logic controller (PLC) with analog inputs, two driving relay sets, two mechanical limit switches, three dc motor and a PV panel supporting metallic structure with mechanical gears mechanism.

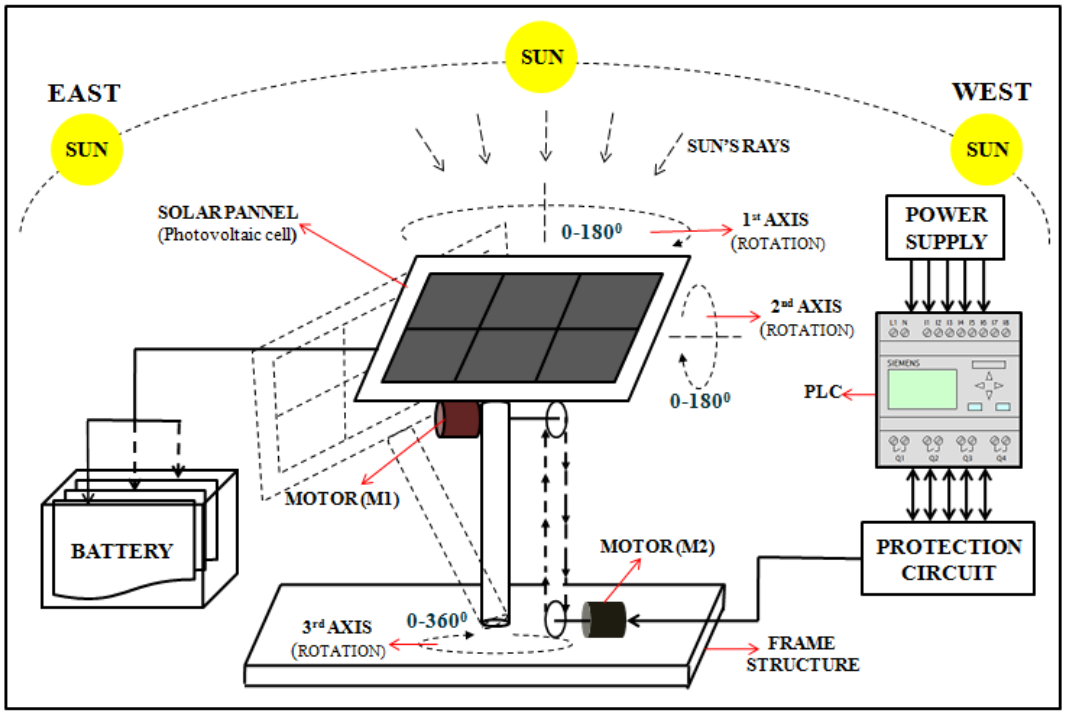

Fig.3 Experimental setup of Three-axis Solar Tracking System

So for observing the efficiency of system the setup is carried out with fixed placement and variable movement of Solar Panel so that we can compare its output value.

2.2.1 Observed Value of Fixed Tilt Angle with Module energy for January Month

Since for fixed angle the panel is placed at 45^0 because this is the standard tilt angle for fixed axis, so the number of days having Fixed tilt angle at which max module energy gained is shown in Table.3 below along with graphical view in Fig.4.

Number of days (n)	Tilt Angle (degree)	Module Energy(kwh/m²/day)
1	45	7.55
4	45	7.56
8	45	7.59
12	45	7.6
16	45	7.65
20	45	7.8

Table.3 Fixed Tilt angle & module energy for the no. of day of January month (Fixed Axis)

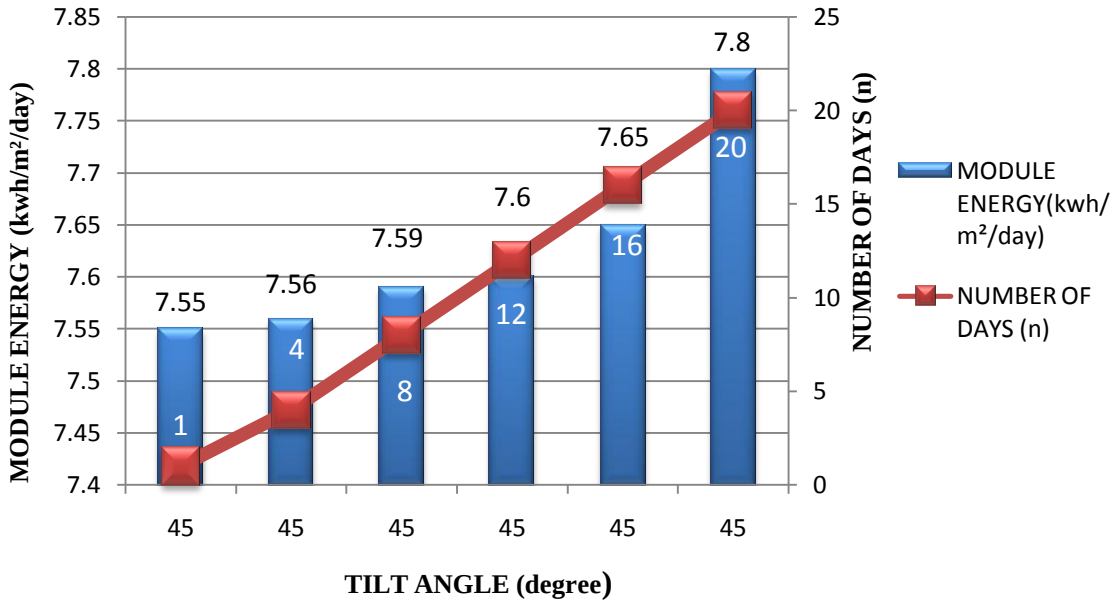

Fig.4 Tilt angle, maximum module energy with number of days for January (Fixed Axis)

Now when we operate the setup, the PLC manipulated all the date which where programmed according to various parameters. The PLC manage the Solar Panel to tilt according to requirement for collecting maximum solar radiation, so the number of days having flexible tilt angle at which max module energy gained is shown in Table.4 below along with graphical view in Fig.5.

Number of days (n)	Tilt Angle (degree)	Module Energy(kwh/m²/day)
1	45	7.55
4	43	8.21
8	41	8.46
12	39	8.7
16	37	9.05
20	35	9.25

Table.4 Tilt angle & module energy for the no. of day of January month (Three-Axis)

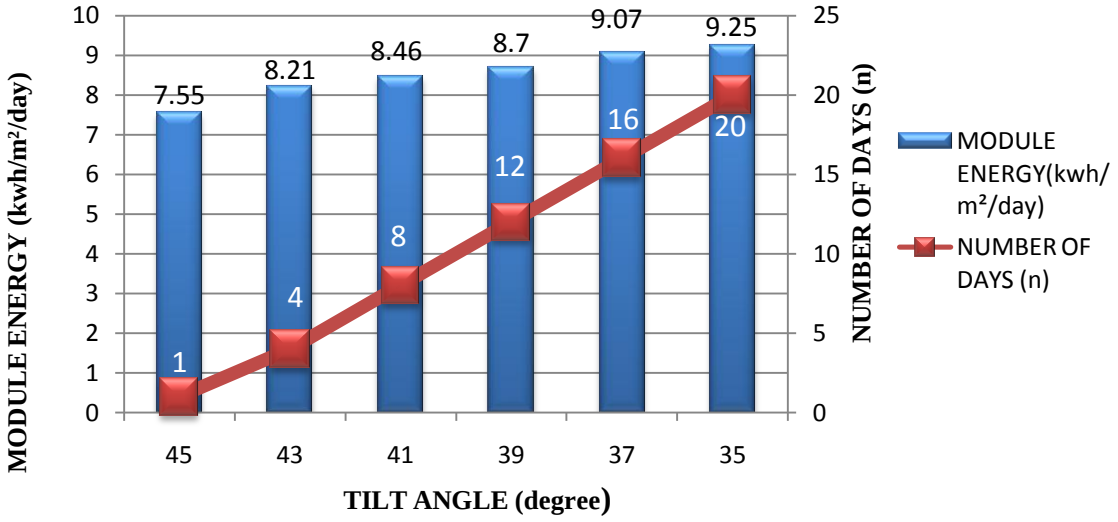

Fig.5 Optimum tilt angle, maximum module energy with number of days for January (Three-Axis)

Now on comparing the maximum module energy which is obtained from Three-Axis Design with respect to the Fixed Axis. The graphical view is shown in Fig.6.

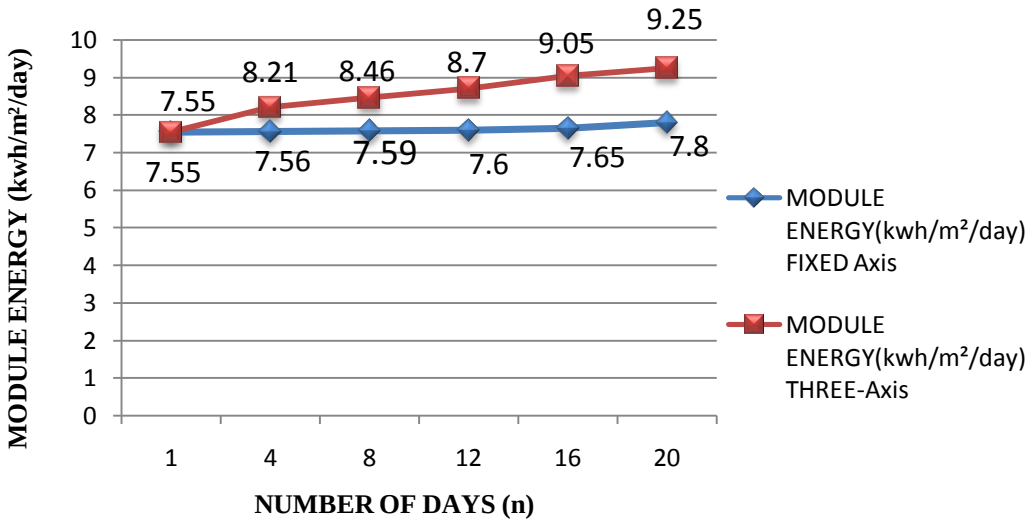

Fig.6 Maximum module energy with number of days for January for (Three-Axis and Fixed Axis)

3. RESULTS

We have found that the optimum tilt angle for Bhilai location at which the panel receive the max energy from sun and give greater efficiency. Range of tilt angle for January is 45°-35°. When we put the panel on its tilt angle based on previous data, it has been found that some energy is lost by falling of solar radiation when we compare the experimental value with

existing calculated data, and on other side there is increment in module energy when we compared Three-Axis model with Fixed-Axis.

4. CONCLUSION

The major issue which we are facing today in using Solar energy is the placement of Solar Panels. When the average resulted value is compared with the experimental value there is 3.06% loss. The loss percentage generally depend on the external factors such weather condition, experimental setup, and other disturbances. On the other side in the Three-Axis model we received maximum module energy which is 11.2% more as compared to fixed axis model. So with the concept of these Three-axis tracking system the power generation will be maximum with greater efficiency as compared to Single axis tracking system. With the help of tilt angle optimization maximum solar radiation will be collected on the solar panel which will be favorable according to the different weather condition.

5. ACKNOWLEDGEMENT

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6. REFERENCE

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