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Effect of Tilt Angle on PV Array Output Performance

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Abstract: ***Solar energy is an effective way to solve the world crisis for energy. In order to reduce cost research about solar energy is being done around the world. While searching about different techniques to increase efficiency and output, various methods present in recent researches. The numbers of factors are essentially important for the study. Tracing mechanism plays a vital role in that aspect. In this method, parameters such as width, height and other are considered. The best is obtained to setup the plant that promises maximum output and reduced cost. Locating the solar panels at different points of incidence to get the maximum power output is aimed in this article.***

Keywords **:** ***Solar panel, tilt angle, sun angle, Irradiance***

I. INTRODUCTION

During ancient times the energy produced in the world depends on sources such as coal, petroleum etc. However, as we move on to the future, those energy resources have started degrading causing a lot of stress around the world. These types of resources also produce ample of pollution, which leads to global temperature increase [1]. Thus, all the people around the world have started to invest a lot of effort in the non-conventional sources of energy which are much safer when compared to other conventional resources [2].

In non-conventional sources of energy, solar takes a major percentage of energy production as all around the globe sun provide energy to every being. Researches all around are taking place to improve the methods of using solar energy [3]. The method applied for it first using steam based technique in which steam is generated using sunlight. Later after the development of photovoltaic cells, the sunlight is directly converted into electricity. The tracing mechanisms are gathering more interest among the researchers. It helps to obtain maximum sunrays without being deflected, thus improving the output power [4, 5].

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II. DESIGN CALCULATION OF PROPOSED METHOD

The initialization of all the input parameters needed for the design is considered as given in table 1.

A. Solar Panel Setting Parameters

Calculating the gap for the solar panels with input parameters. Number of solar panels and the incremental steps of gaps between the solar panels are given in equations (1) and (2).

$$panel_{gaps\left(\frac{panel}{2}+1\right)} = gap_{mirror} \quad (1)$$

$$panel_{gaps\left(\frac{num_{mirrors}}{2}\right)} = gap_{mirror} \quad (2)$$

$$i = \left(\frac{panel1_{mirrors}}{2} + 2\right) : num_{panel} \quad (3)$$

$$panel_{gaps(i)} = panel1_{gaps(i-1)} + gap_{increment} \quad (4)$$

$$i = \left(\frac{panel_{mirrors}}{2} - 1\right) : -1 : 1 \quad (5)$$

$$panel_{gaps(i)} = panel_{gaps(i+1)} + gap_{increment} \quad (6)$$

The above two equations (3), (4) (5) and (6) are used to find out the gap for the subsequent solar panel by taking the gap of the previous solar panel as the base. The position of mirror is depicted in figure 1. Thus, the solar-panel gap for a particular solar panel = (solar panel gap present in the previous solar panels + gap increment)

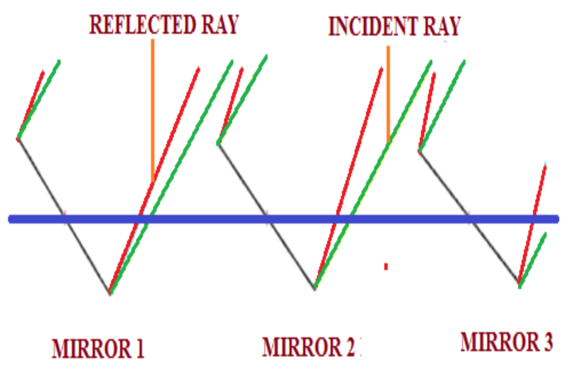

Fig. 1. Positioning of Mirrors

B. Sun Angle

Estimate the sun angle for different times of the day. The orientation is set for +90 degree for afternoon to -90 degree for morning. Figure 2 indicates the co-ordinates for the sun angles.

$$sun_{angle} \geq \left(\left(\frac{pi()}{2}\right) - \left(0.5 * \frac{pi()}{180}\right)\right) \quad (7)$$

$$sun_{angle} = \left(8.95 * \frac{pi()}{180}\right) \quad (8)$$

$$sun_{angle} \leq \left((-1) * \left(\frac{pi()}{2}\right) - \left(0.5 * \frac{pi()}{180}\right)\right) \quad (9)$$

$$sun_{angle} = (-1) * \left(8.95 * \frac{pi()}{180}\right) \quad (10)$$

Table- I: Parameters Specifications

Variable Used	Initialized	Description	Units
sun angle	45	Angle of the sun at various times of the day	Radiant
Num _solar panels	10	Number of solar panels used	Units
Width _solar panel	0.3	Width of each solar panel used	Metres
gap solar panel	0.2	Gap between the solar panels	Metres
gap increment	0	Gap increment with increase in number of solar panels	Metres
do offset	0 1	No offset required Offset required	Logical
offset increment y	0.01	Offset increment in y direction for subsequent solar panel	Metres
offset_ increment x	0.01	Offset increment in x direction for subsequent solar panel	Metres
Receiver height	3	Height of the receiver	Metres
Receiver width	0.4	Width of the receiver	Metres
Receiver depth	0.1	Depth of the receiver	Metres
Aperture width	0	Surface of the solar panel receiving the sun rays	Metres
Footprint	0	The total land area covered	Metres
Shaded aperture	0	The part of the aperture that is shaded	Metres
Received flux	0	The flux that are received on the solar panel	-
total flux	0	The flux that is received from the sun	-
Subtend angle	Calculated	The angle subtended by the diverging sun rays on the solar panel	Radiant

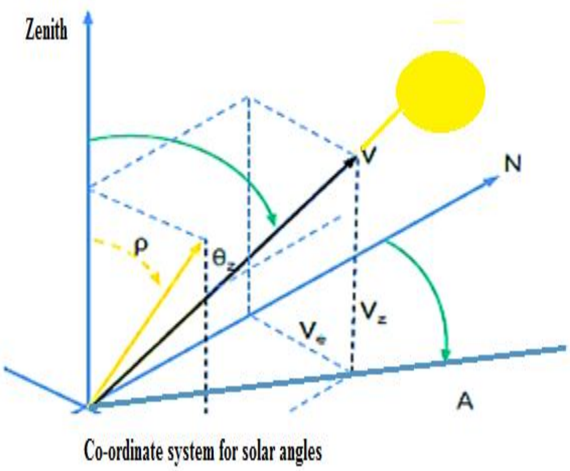

Fig. 2. Co-ordinate system for solar angles

C. Offset With Respect To Sun Position

Then the estimation of offsets for x and y directions need to be performed. Here, offsets- the position in x and y direction. Delta= the relative change in the position for various tilts that occur.

offset_x(t) = 0
offset_y(t) = 0
delta_x(t) = 0
delta_x(t) = 0

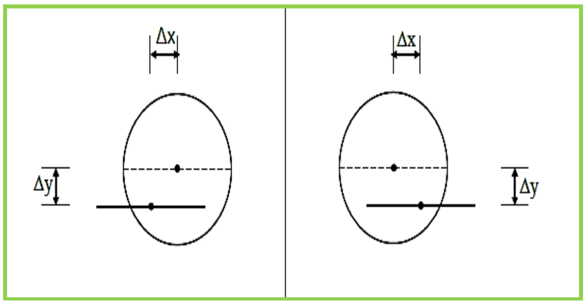

Fig. 3. Offset position

D. Condition of Tilt with Offset

When the offset change there will be a change in position of the centre of the solar panel thus calculating this change in the position of the centre of the solar-panel displayed in figure 3.

$$x_{pos\left(\frac{num_{mirrors}}{2}+1\right)} = \left(\frac{mirror_{gaps\left(\frac{num_{mirrors}}{2}+1\right)}}{2}\right) + \frac{width_{mirror}}{2} \quad (11)$$

$$x_{pos\left(\frac{num_{mirrors}}{2}\right)} = \left(\frac{-mirror_{gaps\left(\frac{num_{mirrors}}{2}\right)}}{2}\right) - \frac{width_{mirror}}{2} \quad (12)$$

Using equation (11) and (12) we can find the offset for any subsequent taking the offset for the previous solar panel as basis. The tilt position is displayed in figure 4. The calculations are as follows:

$$i = \left(\frac{num_{mirrors}}{2} + 2\right) : num_{mirrors} \quad (13)$$

$$x_{pos}(i) = x_{pos}(i-1) + width_{mirror} + mirror_{gaps}(i) \quad (14)$$

$$i = (\frac{num_{mirrors}}{2} - 1): -1: 1 \quad (15)$$

$$x_{pos}(i) = x_{pos}(i+1) - width_{mirror} - mirror_{gaps}(i) \quad (16)$$

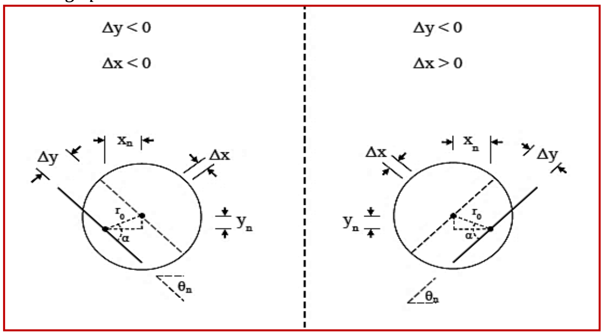

Fig. 4. Tilt position

Solve for thetas where theta is the tilt angle of the solar panel for various offsets.

Offset radius:- $r_0 = \sqrt{(\Delta x)^2 + (\Delta y)^2}$

Angle between r_0 and solar panel surface:-

$$\alpha = tan^{-1}(\frac{\Delta y}{\Delta x})$$

The offset coordinates x and y are,

$$x_n = r_0 * \cos(\alpha - \theta_n)$$

$$y_n = r_0 * \sin(\alpha - \theta_n)$$

The altered geometry causes the offset to be:-

$$\tan(\varphi_n) = \frac{Q_n + x_n}{H + y_n}$$

Where, $\varphi_n = 2\theta_n + \rho$

Here, $\theta_n = tilt\ angle,\ \ \rho = sun\ angle$

$$\Rightarrow \tan(2\theta_n + \rho) = \frac{Q_n + r_0 * \cos(\alpha - \theta_n)}{H + r_0 * \sin(\alpha - \theta_n)}$$

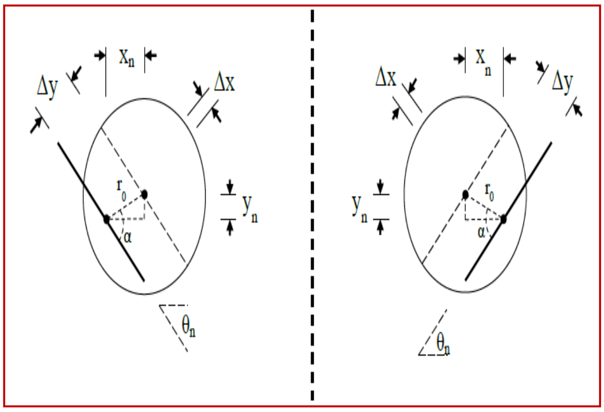

Fig. 5. New position of solar panel

III. RESULTS AND DISCUSSIONS

By taking different values for estimating various parameters, different output is obtained. These characteristics can be compared with each other for getting best result so obtain maximum output. Direct normal irradiance (DNI) density along the receiver is shown in figure 5. The following characteristics are obtained as the output. By changing width or other parameters, we get varying characteristics as the output illustrated in figure 6.

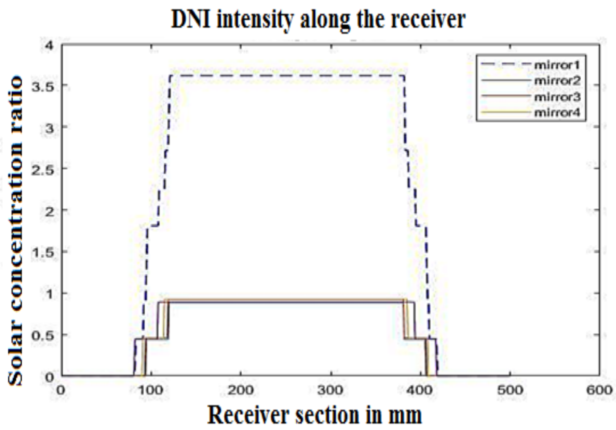

Fig. 6. Direct normal irradiance (DNI) density along the receiver

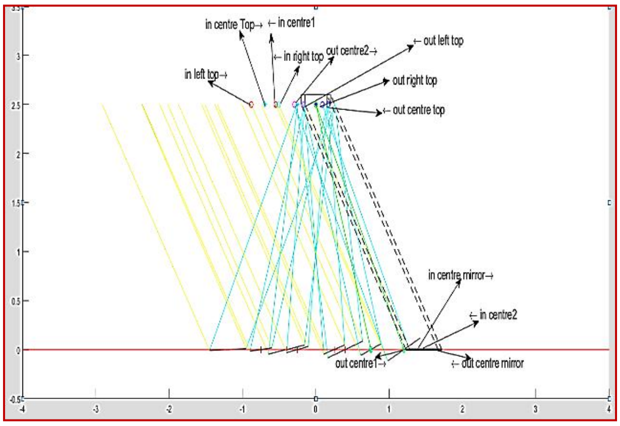

Fig. 7. Analysis for different width

There are number of parameters that can be considered for the change to achieve high output power and to study effect of varying parameter, numbers of tests were done keeping some parameter as constant and varying the others and the change in output energy production is compared.

The effect in output power by changing the number of solar panels is observed by keeping the others parameter constant and same is repeated for different value of each parameter. The table for different value of parameter is shown below:

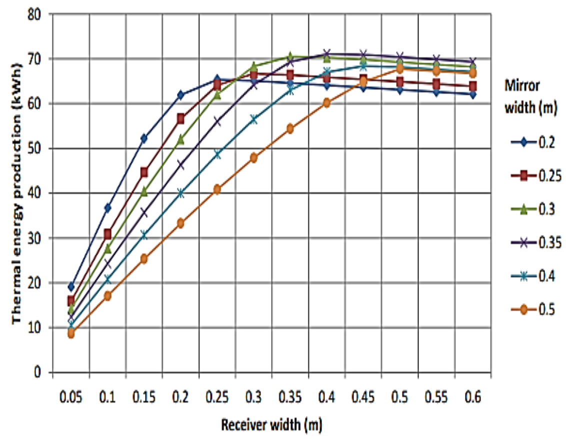

Fig. 8. Thermal energy production

The analyses carried out results in the produced output energy for distinct parameter is similar to the array having 0.01 m solar panel gap. Suited receiver height as showed in above results in the ideal dimensions for a test. In order to test the concept, assume no. of solar-panels for a 0.2 m width solar-panel design must be decreased from 20 to 16 as it will lead to the increase in spacing for testing. 0.2 m width solar-panel design was best suitable for different reasons. First of all, the small solar-panels lead to less blocking loss as shown in figure 7.

Table: II. Result Comparison

Case	Solar-panel width (m)	Solar-panel gap (m)	Receiver height (m)	Receiver width (m)
1	0.2	0.01	2	0.25
2	0.25	0.01	2	0.3
3	0.3	0.01	2	0.35
4	0.35	0.01	2	0.4
5	0.4	0.01	2	0.45
6	0.5	0.01	2	0.55

The gap between the two solar panels is set to be 0.01m which will result in a small gap array. Height of the receiver is set to be 2 m and it can be increased or decreased. The receiver width is basically the width of solar panel and an additional 0.05m for reflected rays which has been diverged. Solar panel number is increased from 2 to 32 in each stage.

The output power is found to increase with an increase in number of solar panel for a particular set of array and the graph plotted is found to be output or thermal energy production is found to increase rapidly for the first number of solar panels but it is found that the output power starts to decrement as the array gets wider which is due to the reflected beam diverging to a greater extent from the receiver. The widest solar panel that can be used is 0.5m wide and this resulted in the great increase in the output rate from table 2. It is found that the increase in the output power is noticeably different which may be useful for a specific design & for the fixed no. of solar panels to be installed. Table 3 shows the best parameter for the best output or the great thermal energy production.

IV. CONCLUSION

Solar energy is a recent approach to resolve the global problems for energy. This study focusses on analysing the effect of different parameters involving in solar energy extraction. Initialising the different parameters and estimating the output system performances is carried out. The solar panel characteristics for various set value of parameters are obtained and the results were discussed. From the different characteristics, the selection of the best way to setup the system for the placement of the solar panel with respect to receiver is chosen to get the best output.

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