Impact of panel shading in the solar panel

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Abstract – The power generation from photo voltaic cell is demonstrated that it is best alternative for power production from non-renewable resources. It assures that it does not cause pollution through power generation. However the power generated by solar panel has significant value only when the solar panel is properly positioned. The solar panel is appropriately placed in such a way that most of the sunrays to be exposed over the panel. To boost the power production, number of solar panel arrays is employed. But, the shadow of one solar panel falls on another one solar panel causes the panel shading. If this occurs then there is a reduction of power generation. So the panel shading and panel spacing is to be considered to extract maximum power from solar panel. **In this paper the variation in power generation is documented for various panel spacing with respect to panel.** Thus, it is possible to place the panel at right position by taking into account of the panel dimensions.

Keywords **– Photo voltaic cell, Panel shading, Panel spacing**

1. INTRODUCTION

The sun has abundant energy and have ability to produce energy for billions of years. Though the sun is 90 million miles from the earth, it takes less than 10 minutes for light to travel from that much of distance. It is the most important source of energy for life forms. India is a hot country and has very high sun irradiation levels. Also India has fast-increasing electricity demand and Indian government has also been moving forward strongly on clean energy. It has a goal to reach 20 GW by 2020 as well [5]. The solar energy available in a year exceeds the possible energy output of all fossil fuel energy reserves in India. It is a renewable source of energy unlike non-renewable sources such as fossil fuels. The main benefit of solar energy is that it does not produce any pollutants and is one of the cleanest sources of energy. It is a renewable source of energy requires low maintenance and is easy to install. The only limitation that solar energy possess is that it cannot be used at night and amount of sunlight that is received on earth is depends on location, time of day, time of year, and weather conditions. The solar energy shall be utilized for power production.The solar energy is converted to electrical energy with the help of solar panels. Solar panel is referred as array of photovoltaic cells. Array of photovoltaic cells are connected in series and parallel manner so as to receive the required amount of power from the panel. Though solar energy is available on a wide scale, it only provides a small fraction of the India's energy supply.However the installation of solar panel is a big concern to acquire or generate required amount of power from the panel.

The things to be considered for accomplishing the notable power generation is as follows

- Solar panel sizing
- Solar panel spacing
- Solar panel shading
- Tilting angle
- Irradiance

The solar panel shading is of two types

Soft shading and Hard shading

Soft shading can be described as simply lowering the intensity of the irradiance levels, without causing any form of visible separation of shaded and unshaded regions. A great example of soft shading would be due to cirrus or stratus clouds evenly blocking out some, but not all of the sunlight. Soft shading cast on a PV cell will cause the cell's current output to proportionally drop. As long as there is enough light (~$50W/m^2$), the voltage output of the cell will remain unchanged and only the current output will diminish. The voltage of the PV cell depends more on temperature and the electron band-gap in the materials than on the light itself.[4]

Hard shading is created when a physical object, such as a shade from a tree or a chimney or shadow of one panel falls over the other is physically obstructing the sunlight, creating obvious visible regions of lit and unlit cells on the array. It's a lot more difficult to describe how hard shade affects a PV cell, as the physical geometry of the shade comes into play. Hard shading refers to shade from a tree or a chimney is shed on the panels. Even one of the panels in the string is covered by darkness the output of the entire string will be reduced to virtually zero for as long as the shadow sits there. If there is a separate, unshaded string, however, this string will continue to produce power as per usual. In extreme cases, a shadow does not necessarily need to fall on an entire panel; shading of even just one cell could flatten the output of the panel and in turn the entire string. Also it creates a problem like hot spots, loss in output power, safety problems. Many modern panels, however, come equipped with devices called bypass diodes which minimize the effects of partial shading by essentially enabling electricity to ‘flow around’ the shaded cell or cells. To avoid shading problems, the panel is properly placed and length of the shadow is calculated. To validate the proposed method, a comparison with traditional methods will be made which represents that with the proposed system output will be obtained for solar hours with shadow free.

2. Methods

The installation of solar panel is more important for generating maximum power from solar panel. The solar panel may be installed in two forms. One is fixed type and other type is movable. In fixed type the solar panels are tilted at the angle so as to maximum solar radiations made to fall on the panels. In movable type, the position of solar panels is moved such that the panels are at right angles with respect to the solar radiations to extract maximum power. The sun's position will be on the far side of the equator for winter months i.e. Sun is the lowest in the southern sky. During the short winter days the Sun does not rise exactly in the east, but instead rises just south of east and it sets south of west. In the figure 1 shows that the sun's position will be on the close side in the summer.ie. The Sun is at its highest path through the sky and the day is the longest. [2] Because the day is so long the Sun does not rise exactly in the east, but rises to the north of east and sets to the north of west allowing it to be in the sky for a longer period of time. When the Sun is high in the sky i.e., summer, the shadows are short. When the Sun is low in the sky i.e., winter, the shadows are the longest

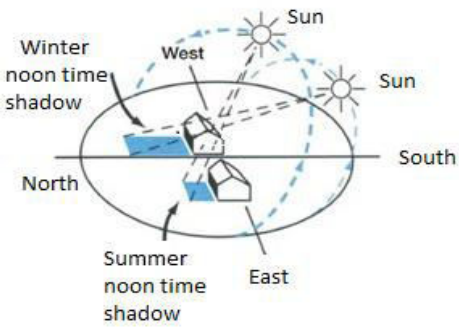

Fig 1.Shadow pattern of sun with respect to summer and winter

If the panels are placed facing north direction then shadow free placement distance between two rows of panels is determined by trigonometric method. For that length of solar panel, angle to which panel is tilted, distance between two rows of panels then the equation for the sunrays to fall on the panel is derived from applying the cosine theorem of spherical trigonometry with consideration of altitude of sun with respect to horizon, latitude angle, declination of earth, hour angle of sun.

In cases of hard shading, there is possibility of shading of one panel array over the other panel may occur. This will consistently reduce the power production. To overcome the problem, the distance between the panels is calculated such that the shadow of one panel array does not fall on the other panel array.

Conventional Methods to calculate the distance between the solar panel for placing it in a shadow free manner

2.1 .Method 1

The distance between two panel is calculated on the basis of consideration of tilt angle of solar panel (β), length of the panel (l) , declination angle of sun(δ) and latitude (φ) where the solar panel is to be located. [1]

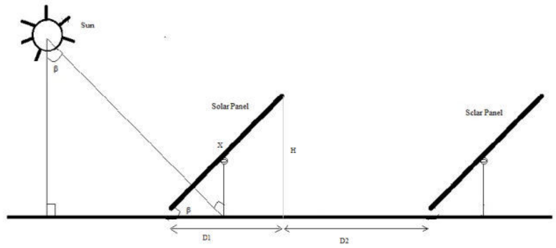

Fig 2. Method 1: Shadow free placement of two solar panels as a function of δ and φ

$$D_1 = l cos\beta \quad (1)$$

$$D_2 = l sin\beta . \tan(\delta + \varphi) \quad (2)$$

$$D = D1 + D2 \quad (3)$$

The figure 2 shows that placement of first row of solar panels over the second row of panels without shading of one panel over the other. For example the for a panel with length l = 1.65 m, tilt angle of β = 12˚, Latitude 8˚56 N and declination angle ˚δ =-23.45˚ then the distance between two rows is 1.52 m

2.2 Method 2

The minimum distance required between two panel for shadow free placement of solar panel is calculated on the basis of consideration of tilt angle of solar panel (β), length of the panel (l), solar altitude angle (α) and azimuth angle (ψ) with consideration of solar hours is 4h.

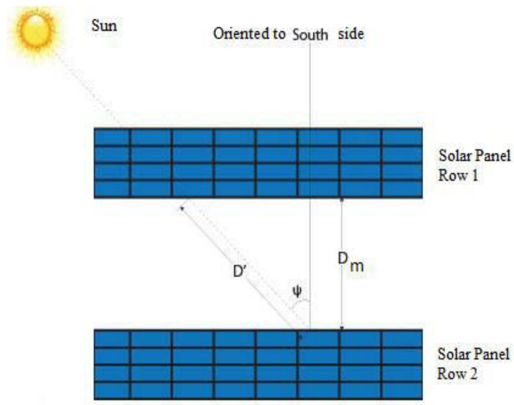

Fig 3. Method 2: Shadow free placement of two solar panels as a function of ψ and α

From the figure 3

$$D^{'} = \frac{l sin\beta}{tan\alpha} \qquad (4)$$

$$D_m = D' cos(180 - \psi) \qquad (5)$$

The figure 3 shows that minimum distance required between first row of solar panels and second row of panels with the condition that shadow of one panel has not be fallen over the other for the solar hours of 4h. For example, for a panel with length l = 1.65 m, tilt angle of β = 12˚, altitude angle 57.5˚ and azimuth angle ψ =-185.5˚ then the distance between two rows is 1.33 m.

2.3 Proposed Method

In the cases of spherical objects like the Earth and the Celestial Sphere, spherical trigonometry is used to work out the space and time equations. In spherical projection method, the radial space from the centre is cosine of the elevation angle. This figure 4 shows that representation of shading of panel with respect to the position of sun. [1] The projection method is used to depict the over head shading of one solar panel over the other.

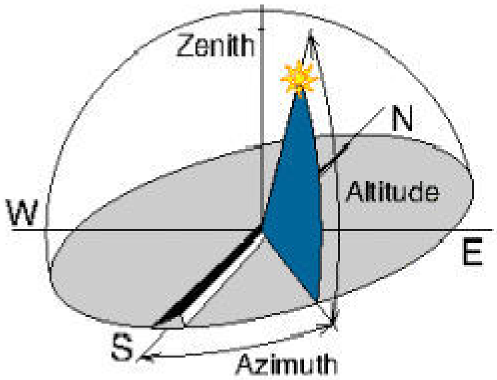

Fig 4. Representation of solar radiation

The distance required between two panel for shadow free placement of solar panel for the proposed method is calculated on the basis of spherical trigonometry with the consideration of tilt angle of solar panel (β), length of the panel (l), solar altitude angle (α) and azimuth angle (ψ) with consideration of solar hours is 4h.

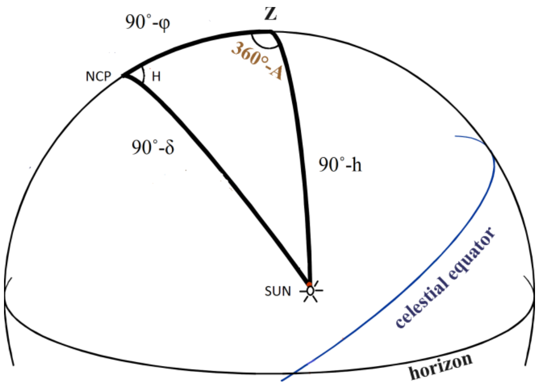

Fig 5. Representation of solar radiation

From the figure 5,
The spherical trigonometry equations are,

$$\frac{\sin(90° - \delta)}{\sin(360° - A)} = \frac{\sin(90° - h)}{\sin H} \qquad (6)$$

$$\frac{\cos\delta}{-\sin A} = \frac{\cos h}{\sin H} \qquad (7)$$

$$\cos\delta . \sin H = -\sin A . \cos h \qquad (8)$$

By applying the first law of cosines of spherical trigonometry to the side (90°-h), the equation achieved is:

$$\sin h = \sin\varphi \sin\delta + \cos\varphi \cos\delta \cos H \quad (9)$$

From the equation (9), the angle of sun with respect to horizon is found for different hour angle. To calculate the shadow, the dimensions of panels and inclinations are required. In addition to that, solar hours play a crucial role in finding the distance of shadow. [3]The solar hour consists of mid peak hour and hour that are distributed evenly, backward and forward from this mid hour. For example, the mid peak hour is taken as H_O =13° at Chennai which is located in GMT+5 and each hour is correlated with average of 15° for solar angle of 8 hours.

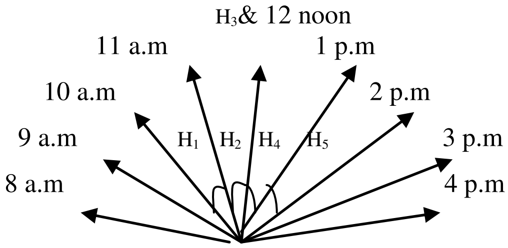

Fig 6. Proposed method: graphic representation of shadow pattern of solar panel

The figure 6 represents that shadow pattern of solar panel with respect to the solar hour. The shadow length is depending on the solar hour and dimensions of solar panel. The total length of the shadow from 10 a.m to 2 p.m i.e. solar angle is 4 h, is calculated from the figure 7.

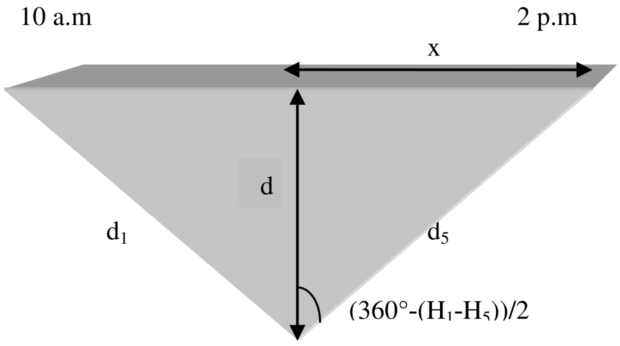

Fig 7. The graphic representation of shadow pattern of solar panel during power generation (from 10 a.m to2 p.m)

The figure 7 depicts that the computation of shadow dimension during power generation phase with the help of solar panel. It also shows that placement of solar panels or minimum distance between solar panels without shading effect during power generation phase. From the proposed system, with the minimum area, the power is generated by means of solar panels with appropriate placement as well as taking into consideration of power generation duration.

3. Results and Discussion

This methodology is applied to analyze with isolated solar power producing unit, consists of number of solar module (60 cells) is built as a string capacity of 6.25 KW with 25 panels. This solar power system has four strings assembled in three rows of array of solar panels. The entire unit is capable of producing 25KW watts. This arrangement is intended to calculate the anticipated shadows on the day of winter solstice. Thereby making possible installation of solar panels is at the minimum distance from the next row of panel is to be found. The latitude for analyzing this power system is taken as 8°56 N and angle of declination δ is -23.45° The calculation of shadows at ortho, h=360° or 0°.With the help of H_1 to H_5 the angles h_1 to h_5 and shadow distance d_1 to d_5 are calculated for solar panel length of 1.65m

Table 1 Comparison of Shadow length for various methods

Tilt Angle β (°)	Methods	Shadow length (m)
12	Method1	1.52
	Method2	1.33
	Proposed Method	1.25
15	Method1	1.66
	Method2	1.52
	Proposed Method	1.33
20	Method1	1.75
	Method2	1.72
	Proposed Method	1.47

4. Conclusions

It is concluded that the proposed method is optimum for placing the solar panel in minimal area to extract maximum power over the specified period of time. It also depicts that tilt angle is also important factor for installation of solar panel. Depending on the latitude the tilt angle should be chosen. Thus placement of solar panel is creating an impact on solar panel for power production.

5. Reference

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