Comparative Analysis of Solar Panel Output Power: Matrix Vs Tree Form

Rahul Deep[1], Abhishek Mishra[1,], and Anshul Agarwal[2]*

[1]*Department of Mechanical Engineering, National Institute of Technology Delhi, Sector A-7, Narela, Delhi – 110040, India*
[2]*Department of Electrical Engineering, National Institute of Technology Delhi, Sector A-7, Narela, Delhi – 110040, India*

Abstract Solar energy is most important form of renewable energy. It is cheap and easily available but it required a lot of area for production of solar power to install them in a particular space. This paper proposes a comparison of solar panel in matrix form and a solar power tree in a particular area. A solar power tree requires very less place to produce efficient energy. Solar Tree is made of metal structure , it has a number of solar panels which are used to give the shape of a tree and arranged in a tall tower. Spiralling phyllataxy is technique used to improve the efficiency of the plant as it prevent the lower panel shadowing. Solar photovoltaic modules are arranged in series form like fibonacci series in place of leaves in solar tree. By using this technique the amount of energy produced by solar tree is more than the energy produce by an array of solar cells. Solar trees are produces about 50% more electricity .The increasing energy demand, economy of land, the solar tree concept is very successful one and should be implemented to provide electricity. Solar tree is much better than the traditional solar PV system in area point of view and also more efficient.

1 Introduction

Solar Energy is the energy from the sun. It is available to every part of earth. But to harness solar energy and to produce electricity effectively is the main problem. As the population is increasing day by day the demand of energy is also increasing. Solar energy reduces the demand to some extent. As a large number of two dimensional solar Photovoltaic (PV) arrays are used to produce electricity. There are many factor on which performance of solar PV depends which include solar irradiance, temperature and condition of climate. In the design of solar panel, solar radiation is very important.Solar tree is a very good application of solar energy. Solar tree is a collection of solar module which is mounted on the branches of solar panel. It collects the solar energy from the sun and converts into useful form of energy. They have a large number of solar module which are tilted at different angle and also at different azimuth angle .They are placed in a certain manner on the tree like for example Fibonacci pattern, spiralling phyllotaxy, single trunk with branches, 3-axis symmetric design, Hemispherical semi-dome design which help to absorb more sunlight. They are made of metal and have leaves in the form of solar module. The main advantage of solar tree is that it required very less space as compared to the fixed solar panel. Solar Tree concept is a mixer of very important and unique art as well as technology which form a solar sculpture [1].In solar tree an attempt is made to use both the solar energy and nature art. It is like a solar panel which is decorated to produce the solar energy. There is an arrangement of solar panel of different shape which resemble like the leave on a tree. It consist of a structure made from steel which have different solar panel at different angle which is used to collect solar radiation and this energy is used to run different electrical equipments [2].To absorbs more solar energy from the sun the structure can be in 3 dimensional forms.[3].As the sun rays incidence angle keep on changing according to season and year, fixed solar panel are not fully utilizing the power it used to produce. Solar panels used to install in the area which required a lot of land which is also a concern to look about[4].To track the sun position sun tracker can be used but it cost very much and their maintenance is also required and also added to the cost also[5]. There are different ways by which solar panel can be mounted on the building which is called as building integrated photovoltaic system[6].TREE in the solar tree stand for T - Tree generating, R – Renewable, E - Energy and E – Electricity [7].

The main aims of solar tree are
- To conserve the land resource

- To increase the efficiency of solar module by arranging the panel

- To create awareness among the people about solar energy

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Corresponding author: abhishekmishra@nitdelhi.ac.in

2 Components of solar tree

There are various component of solar tree which include the following parts:

Solar modules of different shape: Solar modules are of different type like the monocrystalline, polycrystalline, and thin film solar module. They are made up of different material but mostly used material is the silicon material. Silicon is the mostly used material for manufacturing.

Electrical cable: Cable are the material that are used to connect the module so that they can withstand the advance condition in the environment like the wind, snow, high temperature.

LEDs: it can have various LED light, which can work as a street light. It automatically switch ON in night and switch OFF in day light.[8]

Batteries: Battery is another important part of solar tree which store energy and provide as when needed. Some of the batteries used in the solar tree are lead acid batteries, lithium ion batteries and many more.

Inverter: The main uses of inverter are to convert the direct current to alternating current of the solar panel .It efficiency also matters most for power optimization

Stems structure of steel: The structure of solar tree is having no standard structure .It can be design as according to any tree with some modification. Ross Lovegrove design consists of steel pipes of about 5.5m and it has 38 solar panels [9].

There are many differences between solar tree and solar panel which are fixed with respect to various parameters like the land used, cost, orientation, amount of irradiance capture which can understand as given in table below. Mazumder et.al in their research on solar tree designs a model to study the simulation of solar tree and solar panel are oriented at any random angle [10].

3 Parameters used to design solar tree

There are various parameter on which design of solar tree depends which are discuss below:

Ratio of area: It is the ratio of actual area of leaves to the area of Steel structure of solar tree. It increases the area which is capture by the orientation of solar tree.

Orientation angle of different module: As the angle of solar irradiation is changing with different day and according to season. Solar energy is not effectively captured so the module are arrange at a different angle.

Angle of tilt: Tilt of solar module is useful in some cases only. It can capture more irradiance at a particular angle as for small tilt angle which can range from ± 20° and not very good for large angle.

Module size and shape: Solar modules are of different size and also their shape can be changed. As more sunlight is captured by different size and shape module.

Structure design of solar tree: It is the main component of solar tree. Solar modules are installed on the structure. More the height of solar tree more is the capture effectiveness.

4 Mathematical modelling of solar photovoltaic module used in solar tree

Solar tree and fixed tilted solar module are different from other as discussed from below table :

Table 1: A comparison of fixed flat panel and solar tree

Sr. No.	Parameters	Flat fixed panel	Solar tree
	Land used	It uses large piece of land	It required very small area of land
	Cost	It cost is less because of simple design	It have a complex design so more cost
	Amount of irradiance taken per m²	Less irradiance is absorbed	More irradiance is absorb
	Shading	It have less effect of shading	As the panel are oriented at a any angle some shading is present
	Structure	Simple design and no improvement	Very good design
	Orientation of panel	If angle is above 20° they are efficient	If the angle is above 40°-80° solar tree are more efficient

4 Mathematical modeling of solar photovoltaic module used in solar tree

Modelling of solar module is very important as it require tracing the maximum power point. Various elements are used to make equivalent circuit diagram of a real solar module as can be seen from fig.1. The circuit consist of a diode which allow current to flow in a single direction, parallel to this diode a shunt resistance R_{sh} is connected, a series resistance R_s and a source of applied voltage V .Electric current is generated when solar irradiation fall on the solar module[11].
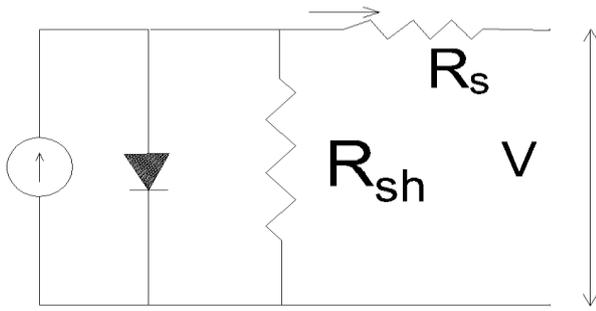
Figure 1: Model of PV cell circuit

Modelling and simulation of solar module is done by using MATLAB/Simulink. To study the characteristic of solar module, the current and voltage are generated by the solar module it's used.

Equation used to model a solar photovoltaic module are given below [11]

Photo-current (I_{ph}) denoted as

$$I_{ph} = I_{sc} + K_i \times (T - 298) \times \frac{G}{G_0} \tag{1}$$

where I_{sc} = Current at short circuit (A)
G_0 = A constant value of 1000 W/m^2 solar radiation
T = Temperature of the solar module (K)
G = Solar radiation falling (W/m^2)

Saturation current (I_0) denoted as

$$I_0 = I_{rs} \times \left(\frac{T}{T_n}\right)^3 \times \exp\left[q \times Eg_0 \times \left(\frac{1}{T_n} - \frac{1}{T}\right) \times n \times k\right] \tag{2}$$

where q = Charge of electron
T_n = Actual temperature (K)
k = Boltzmann constant
Eg_0 = Material band gap (1.1eV)
I_{rs} = Reverse Saturated Current
n = ideality factor of diode (taken as 1.3)

Reverse Saturated Current (I_{rs}) is denoted as

$$I_{rs} = \frac{I_{sc}}{\exp(q \times V_{oc}) \times (n \times N_s \times K \times T)} \tag{3}$$

where N_s = Series cells number
V_{oc} = Open circuit voltage
N_p = Parallel cell numbers

Current in shunt resistance (I_{sh}) denoted as

$$I_{sh} = \frac{(V + I \times R_s)}{R_{sh}} \tag{4}$$

where R_s = Series resistance (Ω)
I = Current (I)
R_{sh} = Shunt resistance (Ω)
V = Voltage (V)

Output Current (I) is denoted as

$$I = I_{ph} - I_0 \times \left[\exp\frac{(V + I \times R_s) \times q}{n \times k \times N_s \times T} - 1\right] - I_{sh} \tag{5}$$

Table 2: The parameter to be keep constant

Parameter	value
Irradiance at normal incidence (G)	1000W/m^2
Cell temperature (T)	25 ° C
Solar spectrum (AM)	1.50

By using the above equation from (1) to (5) are used to develop the model. Two factors which play an important role in developing the model are the irradiance and temperature. To find the effect of one factor other has to be remain constant like to find the effect of temperature on the solar photovoltaic panel the value of irradiance has to be remain constant which can be taken as a standard value of 1000 W/m^2 .Also to find the effect of irradiance on the solar PV module the value of temperature has to b remain constant which have a standard value of 25° C. These various values are used to find the characteristic of a solar module which include the P-V and I-V curve. Comparison of area occupied by solar tree and solar module is important to converse the resources[13].The calculation of power output is done on PVgis and Pvsyst online sources[14].

5 Results and discussions

To compare the area of solar panel, the size of a solar panel is about 65×39 inch^2 = 2535 inch^2 and also 2535 inch^2 = 17.61 Sq. Ft. and the amount of area required by the solar tree is 4 square feet.Let us take 25 number of module which are arrange in a particular way of 5×5 matrix in a linear way on the land so total area occupy by the 25 module is 440.25 square feet. On comparing the area of both solar tree and solar PV system on total area occupied by the solar PV system is 99.14% more than the solar tree.

To do the simulation of solar tree, a 5 KW solar tree which is having 5 panel of power 1KW each and a 5 KW solar photovoltaic system which is fixed at a optimum angle are compared in the New Delhi (28° 50' 34.74" N, 77° 06' 16.34" E) region by using PVGIS simulation software.

First a 5KWp panel is used having the module of crystalline silicon fixed mounting inclination angle of 27° and 180°(south) .Also taking the losses in account annual average power produce is 7188KW.
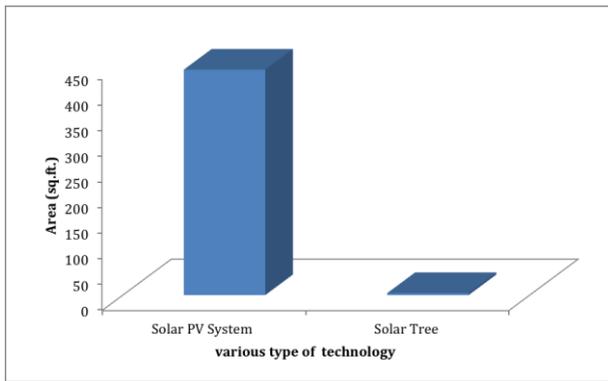
Figure 2: Comparison of area requirement of solar PV system and solar tree

Table 3: power produce at various Tilt and azimuth angle

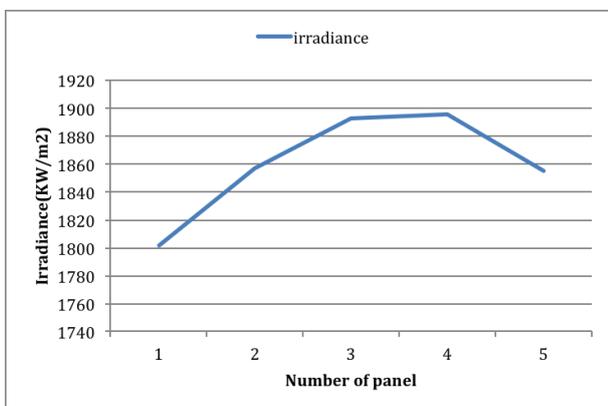| Number of panel	Inclination angle	Azimuth angle	Annul global in-plane irradiation (KW/m^2)	Annual production of power per year (KWh)
1.	40	210° southwest	1802	1394
2.	35	160° south	1857	1441
3.	30	180° south	1893	1485
4.	27	180° south	1896	1457
5.	25	170° south	1855	1435

Figure 3: A curve showing various value of irradiance in different panel

Total energy produce by 5 panel of 1KW peak power at various tilt and azimuth angle are calculated as followed 7212 KWh. The power produce by the a 5 KW solar PV System are as followed at 180(south) azimuth angle and 27 inclination angle the electricity produce is 7190 KWh. Solar tree produce more energy than solar PV system at fixed angle of inclination.
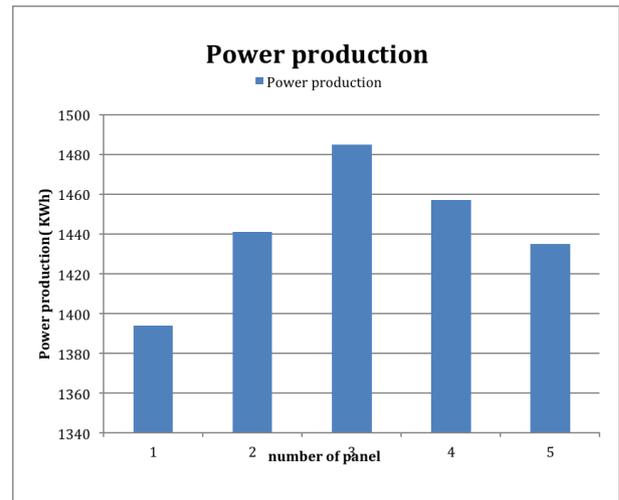

Figure 4: A distribution of power produce in various panels at different angle

6 Conclusions

Solar tree produce more energy than solar PV system at fixed angle of inclination as can be seen from above result. It can be used to produce more power than the fixed solar module. As orientation of solar module is an important parameter is has to be oriented at different angle to collect more solar energy from the sun to produce electricity .It required less space to install solar module as compared to fixed tilted solar module on the large part of land. This reduces the cost of land and can be used to produce more energy. Solar tree have various application which include lighting of garden, highways, parks, street light, urban as well as the rural areas.

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