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Experimental Investigation for photo-voltaic power generation using the concept of solar tree

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Abstract
Solar energy is abundant in quantity and free of cost. Solar PV technology converts incoming radiation from Sun directly into electricity, which makes it one of the most promising renewable technologies available for sustainable development. However, it consumes a large amount of land, which can be used for other human activities. Solar PV tree is a novel technique used for Sunlight capture. It consists of PV panels fixed as leaves on a tree-like structure, and it reduces the land footprint of the PV system.
In this study, the daily energy output of a 36 Watt solar system is maximized. For that, the flexible tree structure is designed. Energy output is maximized by varying the branch angle of the tree structure. Also, comparison of energy output for the standard layout and solar tree of 18 watt is done. The study showed that Solar Tree is a good alternative for the solar power generation instead of conventional layout of photovoltaic generation. Using Solar Tree we can reduce the land footprint area of solar power generation which can save land for other applications. The daily energy output from the Solar Tree can be increased as compared to the standard PV layout. Configuration I, defined in the study is found as optimum at which the energy output increased up to 59.11%.

Keywords: solar, abundant, experimental, generation, investigation

1. Introduction

The proliferating energy demand of the 21st-century modern society is putting immense pressure on the depleting fossil fuel based energy sources of the world. Renewable energy sources are vital to meet the energy demand of the future. Renewable energy based sustainable development have become the main agenda for a clean and green future of the earth. Among all the renewable energy based technologies available commercially, solar PV technology is considered to be mature, stable, and easy to implement and maintain, it is capable of meeting the energy demands with minimal impact on the environment. It involves a photoelectric conversion of incoming photons from the Sun into electricity via a PN junction, usually made with silicon wafers. The PV cell manufacturing process is being heavily researched upon to improve the cell conversion efficiency, reduce the cost of manufacturing and to decrease the energy utilization in the process. Favourable government policies, the uncertainty of grid supply and environmental concerns have contributed towards the rapid development of PV based energy systems around the world in recent years. Solar photovoltaic technology has been noted to be highly beneficial in off-grid rural areas, island nations, and household applications. However despite all the merits, one of the major drawbacks of solar PV is its area requirement; with land being an indispensable necessity for agriculture, transport, industry, and housing, the area requirement of PV systems is to be reduced to enhance its implementation. Rooftop solar PV systems reduce the burden of land required for solar PV systems by installing PV panels on the rooftops of the buildings and houses as well as their facades and walls [1]. Discussed a detailed design and cost analysis for a stand-alone rooftop PV system in India and [2] evaluated the economic viability of rooftop solar for the climate of Iran [3]. Suggested the use of floating solar power plants in their article to reduce the land burden of solar PV systems. Apart from floating solar power plants, recent years have seen an increase in the implementation of building integrated solar PV systems (BIPV) to reduce the land requirement of PV systems. The use of three-dimensional PV structures can also enhance the energy production while consuming less land. The land-based PV systems are usually fixed at a particular set of angles to optimize production during peak Sunshine hours. However, this two-dimensional design of the PV array hampers their effectiveness in Sunlight capture throughout the day and around the year [4]. Pointed out that trees are more effective than PV panels in capturing Sunlight due to the random orientation of its leaves (as some leaves would always encounter normal angles of incidence, although others would encounter grazing angles of incidence) and its three-dimensional structure. One of the routes to solve this issue is the novel concept of a solar PV tree; which is an artistic imitation of natural trees with photo-voltaic panels replacing the leaves and a metal frame taking the place of the branches and trunk. It can generate more power per unit area and capture Sunlight throughout the day owing to its panels being oriented at different angles as discussed by [4] in their simulation study. Various working models of solar PV tree have been demonstrated around the world, some of which are compiled in this thesis further.A solar tree can also be a decorative means of producing renewable electricity. “TREE stands for T = Tree generating R = Renewable E = Energy and E = Electricity". The objectives of a solar tree concept are:-

- To enhance the efficiency of solar PV systems using a three-dimensional structure replicating a natural tree.
- To reduce the land required to harness solar energy.

Solar PV tree consists of solar panels arranged on a steel structure, imitating a natural tree. The main aim of this architecture is to capture Sunlight coming from different directions throughout the day and to reduce the land footprint required by a solar PV system. Since PV panels are more effective in converting direct bean solar radiation, the solar PV tree is designed to cover the Sun path of the location during peak sunshine hours. In present work an attempt has been made to capture sunlight effectively by covering the Sun path of the location in a strategic and organized manner.

2. Experimental set up

To save roof space or to decrease the land footprint of panels is the basic aim of the solar tree. The solar tree consists of solar panels arranged in a tree leaves structure around a pole such that shadow of one panel does not fall on other. Once developed, the solar tree can be installed in public places and along sides of roads. The orientation of panels is free to adjust as our structure used is flexible or with more degree of freedom so that it can be adjust accordingly.

In our solar tree, the panel we have used is rated as follows:-

RATED POWER(Pmax)	3W
Open Circuit Voltage(Voc)	10.8V
Short Circuit Current(Isc)	0.39A
Voltage at maximum Power(Vmp)	8.80V
Current at maximum power(Imp)	0.35A
Maximum system voltage	600V

*Power measured at Standard Testing Conditions(STC): Irradiation 1000 Watt per cubic meter, Temperature 25° C

In our experiment we have calculated the daily energy output of whole tree for this we have made a six sets of two panel which are attach by wires in series connection. After all this both the sets of six panel arranged in parallel connection. Then, the reading of voltmeter, ammeter and ohmmeter are noted by arranging them in circuit as required. At different position of sun the reading get affected to resolve this we have used resistance wire in place of charge controller through which fluctuations get controlled.

For that, we have specified few configurations as follows

C**onfiguration I** All the panels on the right side A- Type branch faced towards 0° south and branch angle of the same branch from the B- Type is 90° .Same as, on the left side towards 0° west and front B- Type at 0° south. Branch angle for left side will also be 90° from the B- type branch..

Configuration II All the panels on the right side A- Type branch faced towards 30° south and branch angle of the same branch from the B- Type is 60° .Same as, on the left side towards 30° west and front B- Type at 0° south. Branch angle for left side will also be 60° from the B- type branch.

Configuration III All the panels on the right side A- Type branch faced towards 45° south and branch angle of the same branch from the B- Type is 45° .Same as, on the left side towards 45° west and front B- Type at 0° south. Branch angle for left side will also be 45° from the B- type branch.

Configuration IV All the panels on the right side A- Type branch faced towards 60° south and branch angle of the same branch from the B- Type is 30° .Same as, on the left side towards 60° west and front B- Type at 0° south. Branch angle for left side will also be 30° from the B- type branch.

3. Result and Discussion

The variation in current output of solar tree with change of branch angle and vertical position of steams are discussed here to achieve the configuration of the branches at which we can get maximum energy output.

3.1 Energy output analysis on configurations

The variation in current output of the tree is shown in Table A.1 and Fig. 6.1.1. The initial current output was 0.89 A and ends at 0.44 A output in this configuration. As the azimuth angle of sun changes the output keep on changing continuously. As the angle between the incident ray and the line perpendicular to the surface changes from zero the output current decreases. The peak output we are getting here is of 1.15 A at 12 Noon. In this configuration there is the rise of 31% to 43.5% in starting (i.e. at 11 o'clock) and also maximum rise in peak current comparing to other configurations is 57.53%.

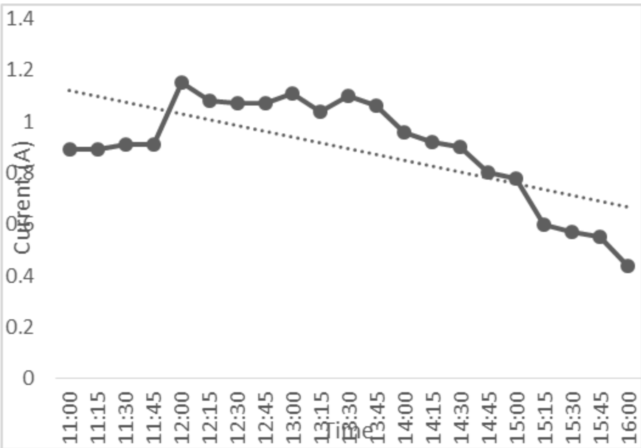

Fig 1: Graphical Presentation: Output current of the tree structure at the configuration of 90° branch angle.

3.2 At 60° branch angle

The variation in current output of the tree is shown in Table A.2 and Fig. 6.2.2. The initial current output was 0.67 A and ends at 0.47 A outputin this configuration. . The peak output we are getting here is of 0.73 A at 12 Noon. In this configuration, less average exposure of all the panels to the sun is there which leads to less current output. Thus, less energy output. There is a loss of 57.5% in this from the 90° branch angle configuration. Peak current rise is of 55.31% in this configuration from the lowest current output (i.e. at 16:00).

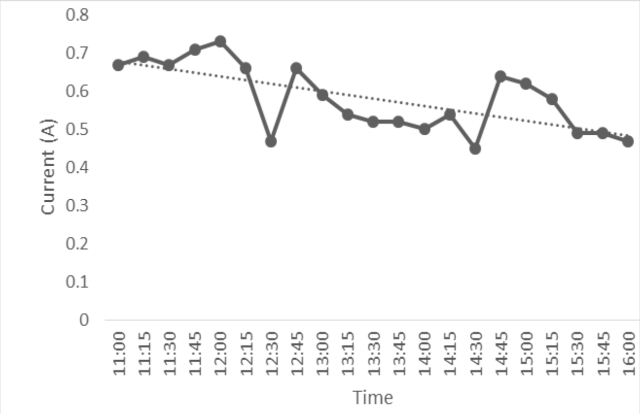

Fig 2: Graphical Presentation: Output current of the tree structure at the configuration of 60° branch angle

3.3 At 45° Branch Angle

The variation in current output of the tree is shown in Table A.3 and Fig. 6.3.1. The initial current output was 0.62 A and ends at 0.45 A outputin this configuration. The peak output we are getting here is of 0.72 A at 13:00. In this configuration, more less average exposure of all the panels to the sun is there between 11:00 to 16:00 which leads to less current output. Thus, less energy output. There is a loss of 59.72% in this from the 90° branch angle configuration. Peak current rise is of 80% in this configuration from the lowest current output (i.e. at 16:00).

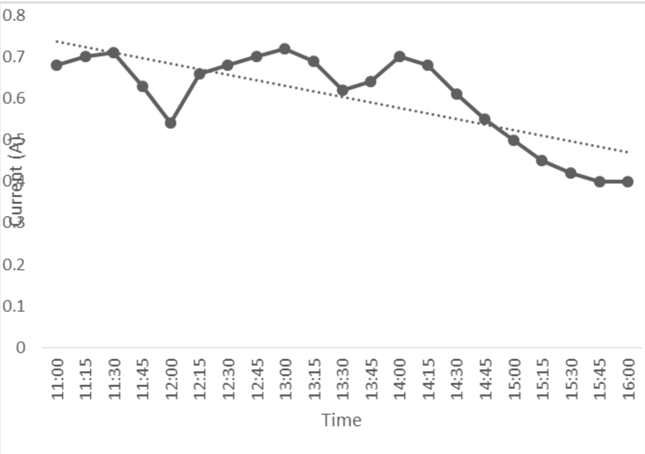

Fig 3: Graphical Presentation: Output current of the tree structure at the configuration of 45° branch angle.

3.4 At 30° Branch Angle

The variation in current output of the tree is shown in Table A.4 and Fig. 6.4.1. The initial current output was 0.62 A and ends at 0.45 A outputin this configuration. The peak output we are getting here is of 0.62 A at 11:00. In this configuration, more less average exposure of all the panels to the sun is there between 11:00 to 16:00 which leads to less current output. Thus, less energy output. There is a loss of 85.5% in this from the 90° branch angle configuration. Peak current rise is of 55% in this configuration from the lowest current output (i.e. at 16:00)

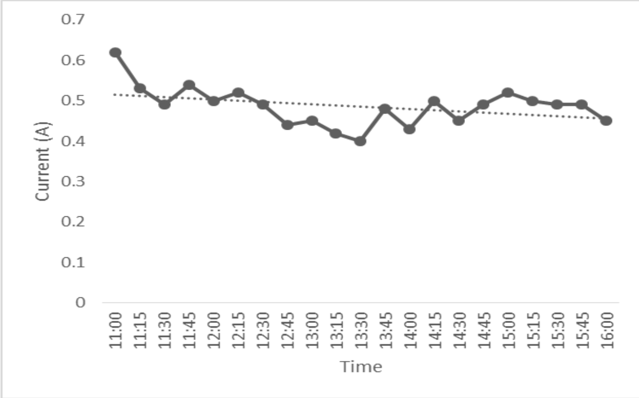

Fig 4: Graphical Presentation: Output current of the tree structure at the configuration of 30° branch angle.

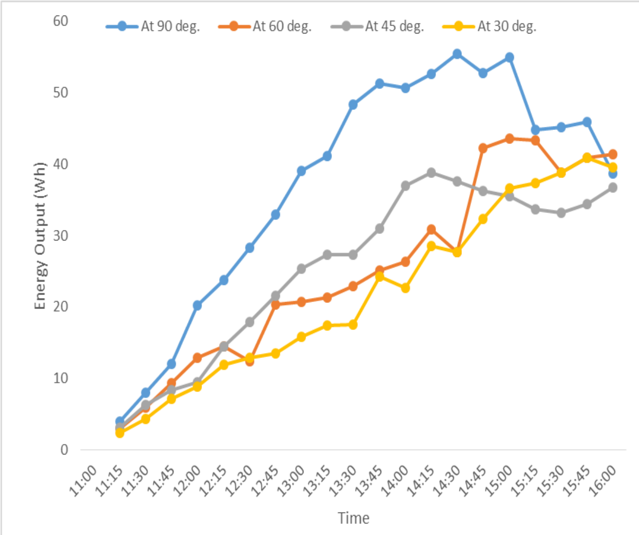

Fig 5: Graphical Presentation: Comparison between energy output obtained from the all the configuration.

4. Comparison of Standard Pv Layout and Solar Tree

Comparison between standard PV layout and solar tree current output is done here. Consider Table B.1 and Fig. 6.6.1.The variation and comparison of current output between standard 18W panels fixed with an inclined hut like structure on the ground and similar type panels attached with the solar power tree at the above optimized configuration (i.e. configuration I). Daily energy output is also done here in Fig. 6.6.2 and Table B.1. The result shows the clear difference between the current output and energy output. There is an increase of 12.74% in the peak value of current, when panels are arranged in solar tree at configuration I.

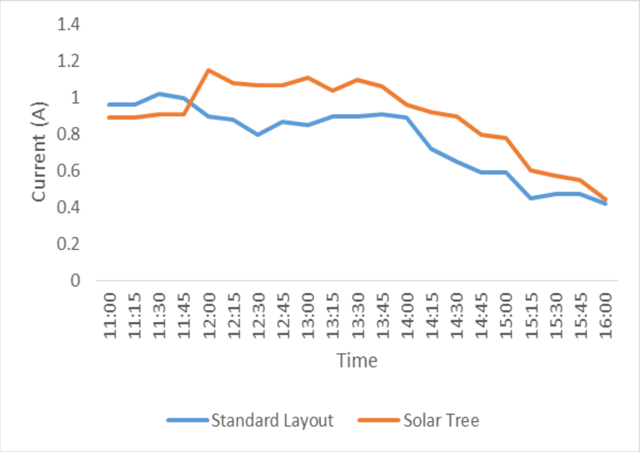

Fig 6: Graphical Presentation: Comparison between current output obtained from the standard PV layout and solar tree.

Conclusions

Following conclusions can be made from the present study

a. Solar Tree is a good alternative for the solar power generation instead of conventional layout of photovoltaic generation.
b. Using Solar Tree we can reduce the land footprint area of solar power generation which can save land for other applications like there are many crops which need less sunshine hours (i.e. 2-3 hours approx.). Those can be grown under the shade of these trees.
c. The daily energy output from the Solar Tree can be increased up to 59.11% than the standard PV layout.
d. Elimination of charge controller/voltage regulator reduces the complexity of system

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