A Complete Survey on Solar Tree Requirement for World Energy Needs

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Abstract— Solar energy is often believed to be the only abundant and free energy resource. Among all the different existing techniques to utilize the sun energy, the well accepted and matured technology is the conversion of solar power into electric power. Despite its advantages, PV technology has issues with the land space prerequisite (especially in urban and semi-urban areas), light absorbing efficiency and people insight (due to the absence of pleasing aesthetics). The notion of a solar tree is proficient in addressing these raised problems efficiently with grace. In this article an honest attempt has been made to review the constituents of the solar tree and its design aspects. The varieties of commercial models are also elaborated along with various applications of the solar PV tree. In this article the major challenges involved with this technology and suggested future research direction have also been discussed.
Key words: Solar Energy, PV Panel, Radiation, Efficiency

I. INTRODUCTION

The expedition for renewable and sustainable power sources has become one of the biggest confronts for the current time, due to the fast depletion of conventional fuels, climatic change, global warming and ever increasing demand for energy [1]. Solar energy embeds heat and light energy from the sun, it is harnessed using varieties of advancing technologies such as solar photovoltaic, solar heating, solar thermal electricity, solar fuels, artificial photosynthesis and solar architecture [2–6]. The most well-liked utilization of solar energy is through the photovoltaic (PV) cells [7–10].

Solar PV capability is dependent on the environmental and availability of solar radiation. Solar radiation appraisal and estimation is very much required for proper design of solar power conversion systems [11, 12]. The incident angle of Sun light varies throughout the whole day and throughout the year. Consequently, solar PV modules situated at a particular angle may not be fully optimally utilized. The installation of solar PV modules has the burden of vast land requirement which will always be a best commodity, particularly in land restricted areas. Rooftop solar PV is a nice-looking choice, but it too has limitation of spaces for PV modules to be positioned in an array. Solar tracking PV systems can be designed but they considerably enhance the total price of power generation as they are very costly and require adequate maintenance. A novel and efficient way to integrate PV into the assembled environment is through building Photovoltaic systems (integrated system) [13–17]. Though more new structures balancing efficiency, land space requirement and general public acceptance might be required. Solar PV trees can be one such novel and inventive concept. In this review article, the idea of solar PV tree technique is detailed through its required components, design parameters and a brief review of presently installed models of the solar PV tree. A thorough comparison with traditional PV system has been done to brief the importance of this novel approach. The major challenges involved in this approach are considered and further suggestions have been proposed to overcome the concerned hurdles. Lastly recent developments of the solar tree are discussed.

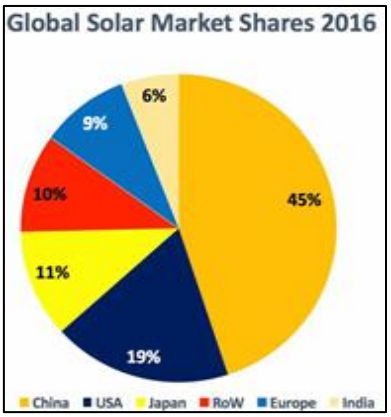

Fig. 1: Solar market 2016

II. SOLAR TREE

The concept of a "Solar photovoltaic Tree" is an exclusive intermingle of skill and technology to form a solar PV carving [18]. This novel idea was developed to utilize the energy from sun in an efficient way. Basically, solar PV tree is an attractive means of generating electricity. The structure of PV solar tree resembles with that of natural tree where solar PV panels are situated as leaves on the branches of the solar tree. It's just similar to natural tree but with solar PV panels instead of natural tree leaves.

"TREE stands for
T = Tree generating
R = Renewable
E = Energy
E = Electricity"

Solar tree embodies a steel structure, on top of which solar PV panels collect photon energy to charge mobile, laptops and small electronic equipments [20]. This can also be used for charging street lamp lights. Since PV panels associated with a solar tree are assembled at various angles, thus a solar PV tree is capable of absorbing sun energy throughout the day. The 3-D arrangement of solar PV tree can supplement the total surface area for sunlight capture. The objectives of a solar tree notion are:

a) To raise consciousness among peoples relative to renewable and sustainable energy.
b) To enhance the public insight about solar PV technology by making it artistically pleasing.
c) To improve the effectiveness of solar PV systems using a 3-D structure imitating a natural tree.
d) To reduce the land space required to harness solar energy.

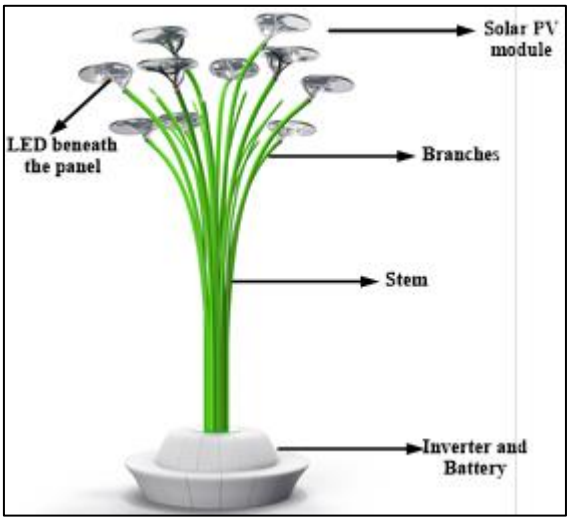

Fig. 2: Layout of Solar Tree


Fig. 3: Layout of Fibonacci Pattern Solar Tree

A. Element of Solar Tree

1) Photo Voltaic Modules

Solar cells manufactured using silicon have highest efficiency for household and commercial application, it is predicted that most of the solar panels being sold worldwide are made up of silicon [22]. The first generation of PV technology includes polycrystalline and monocrystalline solar cells, while sub-sequent generations consists of formless silicon and thin film technology.

2) Inverter

The objective of an inverter is to convert the DC voltage into AC voltage synchronized with grid frequency. The efficiency of a converter is its most important attribute. Modern converters can operate at an efficiency around 98% [13]. The other prominent work of the inverter are maximum power point tracking (MPPT), continuous supervision of the energy produced from the solar plant and protecting the solar plant during faulty conditions by disconnecting it from the concerned grid.

3) Batteries

The batteries used in PV systems must stick to demands of "unstable grid power, heavy charging and discharging period and uneven recharging" [5]. Deep-cycle batteries are used in renewable and sustainable energy applications all over the world for around sveral decades. Some popular batteries used in solar PV system are "lead batteries, lithium batteries, lithium polymer batteries, nickel cadmium batteries" etc. [5].

4) Steel structure

There is no available typical infrastructure for solar tree. The solar tree can be artistically designed in order to make it look attractive pleasing to the public eye and requires less land area. One such novel architecture is of Ross Lovegrove's Solar Tree. Ross Lovegrove's structure consists of steel pipes based sinuous tree, measure 5.5 m, supporting a light bubble in which 38 solar PV panels with 38 watt peak rating, are connected to a concealed 12 Volt battery system which lit an collection of one Watt LEDs at the tip [24].

5) Charging points/ LED's

Solar tree PV panels charges batteries during the day light and a simple methodology can automatically control the switch of LED's during the night time. An internal control architecture controls the amount of light being produced. A photo sensor is deployed to check and record the amount of light in the surroundings and switch On the LED's at the time of dusk and consequently switch to OFF state at the time of Sunrise [25]. The amount of charge stored in the storage system can also be used for charging mobile, electric vehicles and laptops.

B. Applications of Solar Tree

1) Urban Areas

To meet the daily demand for electricity of a domestic consumers while taking very less land.

2) Rural Area

To supply power to rural areas which are disconnected to the grid, to provide electricity to agricultural machines and water pump.

3) Resorts & Golf Courses

To provide electricity for Golf buggies, and other maintenance equipments. Elegant solar tree structures can also enhance the overall appearance of the resort.

4) Highways

To provide street lighting on the highway this would otherwise cost a lot to bring grid energy for lighting the highways. Solar PV tree can be erected on dividers in the middle of the highway.

5) Urban Street Lights

To provide power to street lights in the city. Solar PV tree can be erected road side and it won't cause inconvenience to traffic or pedestrians.

6) Garden Lighting

To fulfill the electricity demands for street lighting in garden and walkways.

7) Recreational City Parks

To make available electric power for protecting the equipment's like grassland cutters, movers etc. and provide electric power to Wi-Fi hubs and mobile/ laptop charging ports.

8) Airports

To supply the electricity required at airport, as they consume large pieces of land for runways, the solar tree can provide energy while requires less land area.

9) Mountainous Regions

To meet the power demands of off-grid mountainous households. The solar tree can be easily fixed on the rough

and sloppy hills and mountains terrain unlike land based Solar PV.

10) Desert Areas

To provide energy for street lighting and shading.

11) Office Car Parks & Industrial Units

To supplement the energy needs of the industry and improve the aesthetics of these areas which are otherwise dull looking. This can improve the work environment.

12) Charging Purposes

To provide power to charge batteries/storage systems which can provide electricity to various electronic appliances like laptops, cameras etc.

13) To Supply Power for Commercials & Display Hoardings.

14) Vending Equipment/Machines, Cooler, Tea Machines.

Parameters	Flat panel PV	Solar Tree
Land footprint	Large-land footprint	Very small land footprint
Cost of PV system	Less due to simple design	More due to complex 3D design
Amount of Sunlight captured per square meter of soil area	Less due to its large array design consuming more area	More as panels are arranged on a tower, which takes lesser area
Orientation of panels	Fixed position of panels	Panels can be oriented at different angles to make capture more effective and flexible.
Art and appearance	Lack of art and aesthetics	Pleasing aesthetic appearance.

Table 1: Comparison of Solar Tree and Flat Panel PV

III. Challenges & Future Development of Solar Tree

In spite of being a very innovative and encouraging technique, solar trees still have drawbacks and challenges that need to be addressed, the following table (Table 2) considers some of the prominent challenges to this technique and proposes necessary corrective measures.

Parameters	Challenges	Suggestion for improvement
Cost	Costly because of steel based structure.	Wooden structure could be utilised in association with plastic renovation.
Design hitches	Highly complex because of copying natural tree structure.	A much simpler design in which all pv panels should be facing common sunlight direction.
Inverter losses	Since each PV panel is installed at a varying angle, all panel absorb a different solar irradiance. Thus, it will have dissimilar I-V and P-V curve. The voltage fixed by the converter will result in stern conversion losses	Using a battery for storing electricity.
Power capacity	Restricted or limited	Separate power converters with battery storage for each solar farm
Reflection hazards	The reflections from PV panel can be dangerous to human eyes. The reason is PV panel are installed at varying angle.	Use of anti-reflection coating over the surface of PV panel.

Table 2: Comparison of Solar Tree & Flat Panel PV

IV. Conclusions

With land always being a valuable and limited resource for human activities, the PV tree idea can be an appropriate answer for urban and semi-urban areas with less spaces. The inspiration of this review is to investigate the range of designs of PV tree and propose future research objectives. After a thorough literature survey on PV solar tree the following key deductions are drawn.

1) PV solar tree can be more effectual than the conventional solar system in terms of sun energy captured all through the day.
2) The effect of grazing angles of solar radiance is insignificant on solar tree.
3) PV tree satisfies today's most pressing social, cultural and environmental, demands with very less land footprint compared to land based PV systems.
4) Solar tree design opens up new panoramas for urban lighting in smart cities with land area constraints, with the help of exciting artistic effects, unlike paradigm flat PV system on land.
5) It is being used for a wide e range of applications including laptop and mobile charging, lighting of streets, supply for household activity, supply to industries, electric vehicles charging and surplus energy can be fed to the grid.
6) Solar PV Tree model can become a design of modern green technology and explore various prospects of research applications in the PV market.
7) However, further thorough research work is highly required in the areas of MPPT technologies and converters for solar PV trees.

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