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AN OVERVIEW OF COMPARISON BETWWEEN 2-DIMENSIONAL AND 3-DIMENSIONAL SOLAR CELL ARRANGEMENTS

[1] NEELAM RAWAT, [2] POOJA SINGH

[1] M.Tech Student Govind Ballavh Pant University of Agriculture and Technology
email id-neelamrawat3049@gmail.com
contact no. 8755363712

Abstract— People all over the world are being aware of harmful effects of burning of fossil fuels for different uses especially electricity generation at present time. And this is the reason people are looking forward to the use of renewable energy sources especially solar energy as sun is not going to run out. In this paper our focus is on differentiating the ways of generation of electricity in different dimensions using solar energy.

Keywords— 2-D, 3-D, Solar energy, Solar Photo-voltaic, Solar Power Tree (SPT), Fibonacci, Phyllotaxy

INTRODUCTION

At the present time people are being aware of the importance of use of renewable energy sources in which solar energy resource is playing a crucial role. Initially for the most efficient use of solar energy solar panels as made of crystalline Si are mounted on rooftop of houses at some tilt angle as well as laid on some hut-like structure. This complete arrangement can be treated as 2-D structure which takes a lot of space and also have other drawbacks and to remove them solar panels are arranged in a 3-D structure and termed as Solar tree which use solar energy most efficiently per installation area. Solar power can be harnessed in different ways as via solar thermal technology, passive solar heating, PV cells etc. Among all these technologies, PV technology is simple, less costly and efficient comparatively. While comparing conventional PV modules installed on inclined hut-like structure with respect to Solar tree design one can treat conventional PV modules as 2-D structure and Solar tree as 3-D structure as in solar tree solar panels are installed in different azimuth and collect solar energy from different direction. Although both technologies include combination of solar panels in which they are arranged differently.

HISTORY OF PV MODULE

Solar power technology is not a recent technology. In mid 1800 solar power plants were developed to heat water so that steam can be generated for driving different machines. In 1839 **Alexander Edmond Becquerel** claimed that "shining light on an electrode submerged in a conductive solution would create an electric current" but he could not explain the effect. This was explained only after in 1905 when **Albert Einstein** published a paper on Photoelectric effect according to which many metals emit electrons when light shines upon them. In 1873 **Willoughby Smith** discovered the photoconductivity of Selenium while testing materials for underwater telegraph cables. In 1883 **Charles Fritt** made the first selenium solar cell but their efficiency of conversion was less than 1% and hence, they were not very practical. Research on Selenium PV continued for next several decades but they were not efficient enough to be put to widespread use. Over 100 years later, in 1941 **Russell Ohl** invented the solar cell, shortly after the invention of transistor. Si solar cell invented by Russell Ohl was 1% efficient but was not in practical use. In 1953 **Gerald Pearson**, **Calvin fuller** and **Daryl Chapin** discovered the Si solar cell. They showed in their research that by adding suitable impurities to Si, efficiency of solar cell improved. This cell was efficient enough to run small electrical devices. After some improvements in their design they combined together several solar cells and named this design Solar battery which is also known as solar panel. Conversion efficiency (converting solar energy into electricity) of these solar cells was 6%. In 1953 first solar cells were available commercially.

CONSTRUCTION AND WORKING OF SOLAR CELL

Solar cell is usually made of silicon. In crystalline form Si behaves like a semiconductor and hence is a poor conductor of electricity. To improve its conductivity pentavalent and trivalent impurities are added. This process of adding impurities is called doping. By adding trivalent and pentavalent impurities to Si, p-type and n-type Si is formed which have free electrons and holes respectively. When p-type and n-type Si comes into contact electrons move towards the p-side and come into contact with holes. After some time an equilibrium state is reached and electric field across the junction separates these two sides. When solar light hits solar cell, electron-hole pairs break apart due to its energy. Electric field across the junction doesn't allow free electrons to move towards the n-side. And when an external path is provided electrons flow through this path and meet the holes in p-side. Flow of electrons through external path result into current and electric field across the junction causes voltage. Power is obtained using values of voltage and current. This overall phenomenon is called Photovoltaic effect. PV modules are made by connecting several individual cells together to achieve useful levels of voltage and current. To generate electricity at a large scale several pv modules are arranged in series and parallel combination resulting into a PV array.

TYPES OF SOLAR PANEL

There are different types of solar panel as follows:

(1) Crystalline solar panel

(i) monocrystalline

(ii) polycrystalline

(iii) string-ribbon

(2) Thin –film solar panel

(i) Amorphous-Si

(ii) Cadmium telluride

(iii) Copper indium gallium selenide

(iv) Organic photovoltaic cell

Crystalline Si forms the basis of mono and polycrystalline Si solar cells. **Monocrystalline** solar cells are also called single crystalline Si. These solar cells are made out of cylindrical Si ingots. To optimize performance and lower costs of a single monocrystalline solar cell, four sides are cut out of the cylindrical ingots to make silicon wafers.

Advantages:

- Monocrystalline solar panels have the highest efficiency rates (21.5% till April 2013) since they are made out of the highest-grade silicon.
- Monocrystalline silicon solar panels are space-efficient and also produce upto four times the amount of electricity as thin-film solar panels.
- Monocrystalline solar panels live the longest.
- At low light condition perform better than same rated poly-crystalline solar panels.

Disadvantages:

- Monocrystalline solar panels are the most expensive.
- If the solar panel is partially covered with shade, dirt or snow, the entire circuit can break down.
- During the process of production of monocrystalline Si through Czochralski process, a significant amount of Si ends up as a waste.

Polycrystalline Si solar panels were introduced in 1981 commercially. Unlike monocrystalline solar cells these cells are perfectly rectangular with no rounded edges.

Advantages:

- The amount of waste Si is less comparatively.

Disadvantages:

- Efficiency of polycrystalline solar panels is 13-16% due to lower Si purity.
- Lower space efficiency.

String ribbon solar panels are also made out of polycrystalline Si. String Ribbon is the name of a manufacturing technology that produces a form of polycrystalline silicon.

Advantages:

- The manufacturing of these solar panels only uses half the amount Si as monocrystalline manufacturing and this contributes to lower cost.

Disadvantages:

- The manufacturing of String Ribbon solar panels is significantly more energy extensive and more costly.
- Efficiency is at best on par with the low-end polycrystalline solar panels at around 13-14%.In research laboratories, researchers have pushed the efficiency of String Ribbon solar cells as high as 18.3%.

- String Ribbon solar panels have the lowest space-efficiency among crystalline based solar panels.

Thin-film solar cells are also known as thin –film photovoltaic cells. Depositing one or several thin layers of photovoltaic materials on substrate is the main gist of how thin film solar cells are manufactured. Depending on the technology, thin-film module prototypes have reached efficiencies between 7–13% and production modules operate at about 9%. Future module efficiencies are expected to climb close to the about 10–16%. Solar panels based on Amorphous silicon, Cadmium telluride and Copper indium gallium selenide are currently the only thin-film technologies that are commercially available on the market.

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Amorphous-Si solar cells have only been used for small scale applications such as in pocket calculators due to low output of electrical power but recent innovations have made them more attractive for some large applications too. With a manufacturing technique called "stacking", several layers of amorphous silicon solar cells can be combined, which results in higher efficiency rates (typically around 6-8%). Only 1% of the silicon used in crystalline silicon solar cells is required in amorphous silicon solar cells. On the other hand, stacking is expensive. **Cadmium telluride** is the only thin film solar panel technology that has surpassed the cost-efficiency of crystalline silicon solar panels in a significant portion of the market (multi-kilowatt systems). The efficiency of solar panels based on cadmium telluride usually operates in the range 9-11%. **FIRST SOLAR** has installed over 5 gigawatts (GW) of cadmium telluride thin-film solar panels worldwide. The same company holds the world record for CdTe PV module efficiency of 20.4% in February 2014. **Copper indium gallium selenide** solar cells have showed the most potential in terms of efficiency as compared to other thin film technologies. These solar cells contain less amounts of the toxic material cadmium that is found in CdTe solar cells. Commercial production of flexible CIGS solar panels was started in Germany in 2011.The efficiency rates for CIGS solar panels typically operate in the range 10-12 %. Swiss researchers have claimed a new world record efficiency of 18.7% for flexible copper indium gallium (di) selenide solar cells on plastics.

On comparing all types of solar cells it can be concluded that monocrystalline solar cells are the most space efficient but also more expensive while the thin film solar cells are less costly but the least efficient.

NEED FOR NEW INVENTION

Generally in solar power generation system PV panels are erected under the sun so that the surface of panel gets the maximum insolation of the day being laid at an angle. For more power in kilowatts it is required to have suitable structure over the landed area in an open space to hold the solar panels therefore hut like permanent fixed structure are made. But these structures require large area of land surface in acres for housing the panels to generate power in MW. And land is already a burning crisis in most of the countries. Again most of the agriculture areas are in need of electricity but are far away from the conventional power plants. And it would be uncountable loss if land is used for other purposes than agriculture. Hence, using vast land, for capturing solar power would never be cost effective and viable for human being. Hence there is a need of such design which can absorb solar radiation without occupying much surface area. Design should be capable of absorbing maximum solar power by providing maximum solar surface along with utilizing minimum land.

SOLAR POWER TREE

Here comes the idea of a Solar power tree a new invention of installing PV modules on a tall pole like structure with leaf like branches surrounding it following a pattern of spiraling Phyllotaxy as found in a natural tree. Solar tree is a revolutionary urban lighting concept as it satisfies all environmental, social, cultural and aesthetic demands. It represents solar energy technology in an artistic way.

HISTORY OF SOLAR TRE

In 1998 a number of sculptural structures incorporating solar photovoltaic cells had been erected among which a solar tree of capacity 7KW was presented by Gleisdorf, Austria. After that **Ross Lovegrove** designed a solar tree based on shape of coconut tree. His tree design consisted of steel pipes of height 5.5meter supporting a light bubble in which 38 solar cells of 38watt capacity each was connected to a 12v hidden battery system. And 1 watt Led's of different color was installed on tip of bubble. In this design the solar tree panels charged batteries during the day and at dusk it automatically switched on its Led's. The internal control was used to regulate amount of light produced according to the availability of charge left in batteries. In 2007 Lovegrove received Vogue Traveler Ecology Prize for his work with Solar Tree. **Milos Milisavljevic (2010)**, founder of 'The Strawberry Energy' a Serbian company, invented a solar tree specifically to charge mobile devices and installed it in the main park of Obrenovac municipality, Serbia. Its main parts were solar panels, rechargeable batteries which could make tree function for 14 days without sunshine, 16 cords for different type of mobile devices and small electronics which maintained balance between produced and consumed energy. **Asai Yuji** and **Toshiaki Yachi (2010)** presented a research paper in which they proposed a design of solar PV modules assembled three-dimensional structure which enabled more efficient conversion of limited amount of solar light using low cost solar cells. The proposed PV modules were tree shaped. Using simulation method they showed that these modules produce more electricity as compared to panels arranged in a conventional way. This solar tree design maximizes power generation per installation area and uses the solar energy effectively. **Aidan Dwyer (2011)** proposed a solar tree design during his research on the patterns of natural trees. He found that leaves and branches follow a specific pattern due to which they avoid shade from each other and find maximum sun exposure. This pattern is termed as Fibonacci pattern which was first discovered by Leonardo of Pisano while solving a math puzzle. Aidan's tree was based on this pattern and he claimed that this solar tree was more efficient as compared to conventional panel of same rating. **Marco Bernardi. *et al.* (2012)** proposed a paper in which they formulated the problem of PV based power generation in three-dimensions. This paper showed that 3DPV structures (Solar tree) could be realized practically and could improve solar energy generation as compared to flat panel. They concluded that 3DPV structures could use more number of hours per day for solar energy generation as well as might be enabled the design of sunlight concentrators using mirror. **V. Avdic. (2013)** proposed a paper which elaborated the possibility of building a solar tree in Sarajevo. Goal of this project was to achieve satisfying outcome which include multifunctional role (street light, mobile, laptop charging etc.), durability, aesthetically, economical and ecological acceptable. And to harness solar energy in an optimum manner various designs of solar tree are being proposed and solar tree has become a field of great research.

CONSTRUCTION AND WORKING OF SOLAR PANEL

Main important parts solar tree include in its design are Solar Panels, Batteries, LEDs, Batteries, Long Tower and Stems for connecting solar panels. Batteries are charged during the day and at dusk LEDs are automatically switched on and indicate how much energy is left. Batteries are used to store the energy so that it can be used in the night time and also during cloudy days.

ADVANCED SOLAR TREE

Fibonacci sequence: - Leonardo of Pisano developed the Fibonacci sequence that is given by Fn=Fn-1 + Fn-2. In this pattern next number in sequence is the result of sum of two previous numbers. In this sequence ratio of each number to its previous number settles to a value called Golden Ratio and is equal to 1.618034. This type of sequence is found in Oak tree, Elm tree, Almond tree etc. A naturalist Charles Bonnet observed that plants sprout their branches and leaves in a Fibonacci pattern such that leaves above do not hide below leaves and each gets a good share of sunlight. This whole arrangement is termed as Phyllotaxis and can be shown in fig. (a).

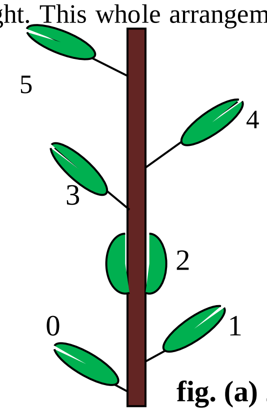

fig. (a) 2/5 phyllotaxis

Design of Advanced Solar Tree: - Design of this Solar Tree is based on the design of Oak tree. It is called advanced because as compared to other design this design is more efficient as solar panels used in this follow Fibonacci pattern. On the Oak tree Fibonacci pattern is 2/5 which means that spirals cover 5 branches to spiral two times around the trunk to complete one pattern. Following this pattern Solar Panels are placed in different directions and thus receive solar energy during whole day time. This pattern places each Solar Panel in an optimum position so that each panel can receive maximum solar energy and also avoid shade from each other. Fibonacci pattern collects more sunlight when sun is at low angle and is extremely useful in winter season and in extreme latitudes.

SOLAR TREE IS BETTER THAN CONVENTIONAL PV TECHNOLOGY

Solar tree is better than conventional pv technology in several manners as it requires less land comparatively (requires 1% land as compared to conventional method). Solar tree can generate electricity very efficiently due to spiral phyllotaxis technique (one stem at each node) resulting into Fibonacci pattern. Solar tree also can collect energy from wind by making stems of tree flexible so that they can rotate in any direction and can produce electricity by shaking themselves. Solar tree uses the maximum hour of sunlight during whole day time comparatively as solar panels used in this capture sunlight in different directions. There are so many other advantages which proof solar tree is better than conventional pv technology to capture sunlight.

Disadvantages of Solar tree:-

- Installation cost is high.
- Hazards to eyesight from solar reflectors as well as may cause hazards to birds and insects.

CONCLUSION

As Solar PV technology for generating electricity is conventional as compared to Solar Power Tree technology hence it is widely adopted but solar power tree is a new method of generating electricity in more efficient way and it also overcomes the drawbacks of conventional method. It is the best option for generating maximum electricity using minimal land.

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