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Improving the efficiency of solar photo voltaic system using organic solar cell and fuzzy logic based tilted panel sun tracking system

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Abstract: Organic solar cells (OSC) represent a young photovoltaic technology that uses organic semiconductor materials to convert sunlight into electricity. These materials can be deposited at low temperatures in a continuous process on flexible substrates, enabling a very high throughput. As a consequence the production costs are dominated by the material costs. The technology used for the manufacture of solar cells is predominantly silicon based an inorganic material. The semiconductor industry developed a deep understanding of the properties of this material, allowing for an easy transfer for use in the solar cell as a solar cell practically mimics the operation of a semiconductor wafer, in that it allows for the transport of an electric current. In this paper a program is written in C++ to estimate the solar radiation in different areas and calculate the total power which can be generated through the solar energy. It also calculates the angle at which the solar panel is fixed to trap maximum solar radiation. Then a fuzzy logic based C++ program is written to track the solar panel by sensing the voltage and temperature of the panel. For computing the solar radiation different inputs such as monthly average global radiation, regression constant, extraterrestrial solar radiation, declination angle, latitude angle etc. were noted. When these inputs are given to the written program then it will automatically give the total possible energy production through the solar radiation. We use organic solar cells has low production costs in high volumes. Combined with the flexibility of organic molecules, organic solar cells are potentially cost-effective for photovoltaic applications. Thus, it costs approximately five times as much for electricity from solar cells. If the cost of producing solar cells could be reduced by a factor of 10, solar energy would be not only environmentally favorable, but also economically favorable.

Keywords: Organic Solar Cell, C++ programming, Solar radiation, Declination angle, Photovoltaic cell.

I. INTRODUCTION

The amount of energy that the Earth receives from the sun is enormous: 1.75 × 1017 W. As the world energy consumption in 2003 amounted to 4.4 × 1020 J, Earth receives enough energy to fulfill the yearly world demand of energy in less than an hour. Not all of that energy reaches the Earth's Surface due to absorption and scattering, however, and the photovoltaic conversion of solar energy remains an important challenge. State-of-the-art inorganic solar cells have a record power conversion efficiency of close to 39%, while commercially available solar panels have a significantly lower efficiency of around 15–20%. Another approach to making solar cells is to use organic materials, such as conjugated polymers. Solar cells based on thin polymer films are particularly attractive because of their ease of processing, mechanical flexibility, and potential for low cost fabrication of large areas. Polymer solar cells have many intrinsic advantages, such as their light weight, flexibility, and low material and manufacturing costs. Recently, polymer tandem solar cells have attracted significant attention due to their potential to achieve higher performance than single cells. Photovoltaic's deal with the conversion of sunlight into electrical energy. Organic or plastic solar cells use organic materials (carbon-compound based) mostly in the form of small molecules, dendrimers and polymers, to convert solar energy into electric energy. These semiconductive organic molecules have the ability to absorb light and induce the transport of electrical charges between the conduction band of the absorber to the conduction band of the acceptor molecule. There are various types of organic photovoltaic cells (OPVs), including single layered and multilayered structured cells. Both types are currently used in research and small area applications and both have their respective advantages and disadvantages Thin film photovoltaic cells based on solution process able organic semiconductors have attracted remarkable interest as a possible alternative to conventional, inorganic photovoltaic technologies. The following key advantages of organic photovoltaic devices have been identified:

1) Low weight and flexibility of the PV modules.
2) Semi transparency.
3) Easy integration into other products.
4) New market opportunities, e.g. wearable PV.
5) Significantly lower manufacturing costs compared to conventional inorganic technologies.
6) Manufacturing of OPV in a continuous process using state of the art printing tools.
7) Short energy payback times and low environmental impact during manufacturing and operations.

The demand for high efficient and affordable solar photovoltaic technologies had resulted in widespread research and development of various technologies

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including organic solar cells, dye sensitized solar cells, quantum dot solar cells etc. Of all the upcoming alternative organic solar cells possesses distinctive advantages such as low cost, made of abundant earth materials, simple manufacturing techniques and ability to incorporate various other technologies. The current highest reported efficiency of organic solar cells are above 10% and it is widely regarded that the lower operating efficiency of organic solar cells compared to that of typical silicon solar cells doesn't hinder the commercialization potential of organic cells due to its other advantages. Although many other technical limitations and drawbacks including low stability and lifetime, limitations in understanding of basic device physics etc. are to be addressed in the very near future as the technology is on the verge of mass commercialization. Fuzzy control has adaptive characteristic in nature, and can achieve robust response of a system with uncertainty, parameter variation and load disturbance. It has been broadly used to control ill-defined, non-linear (or) imprecise system. Fuzzy logic controllers have the advantages of working with imprecise inputs, not needing on accurate mathematical model, and handling nonlinearly. Fuzzy control has been successfully applied in many fields. Fuzzy control does not require accurate models of control object to overcome the limitation of the above conventional tracking methods, fuzzy control is applied to deal with MPPT of PV generation system in this paper, with this technique, not only can the real MPP be readily tracked but also fast dynamic responses can be achieved.

II. ORGANIC SOLAR CELL

Recently, organic solar cells are attracting a lot of attention due to flexibility, low cost, light weight and large-area applications, and significant improvement in the power conversion efficiency.

A. Organic solar cell Vs Photovoltaic cell

A fundamental difference between solar cells based on organic materials and conventional inorganic photovoltaic (IPV) cells is that light absorption results in the formation of excitons in molecular materials, rather than in free electrons and holes. An exciton in an organic semiconductor can be considered as a tightly coulombicly bound electron hole pair. Due to its electrical neutrality and the strong binding energy between the hole and the electron it can be regarded as a mobile excited state. Due this fundamental difference the processes involved in the conversion of photons into electrical energy are not the same as those occurring in IPV cells. Some more relevant properties of organic materials based on dye molecules or on polymers.

By studying the photovoltaic properties of organic solar cells it is possible to influence the short circuit current (I_{sc}), the open circuit voltage (V_{oc}), the fill factor (FF), hence the cells efficiencies can be improved. The characteristics of organic solar cell impact on the conversion efficiency of organic solar cells, including the series resistance (R_s), the shunt resistance (R_{sh}) and so on. A circuit model of the solar cell provides a quantitative estimate for losses in the solar cell to interpret the characteristics of the solar cell. The conventional circuit model which is suitable for inorganic solar cells has emerged. However, compared with inorganic solar cells, organic solar cells are lack of a three-dimensional crystal lattice, different intramolecular and intermolecular interactions, local structural disorders, amorphous and crystalline regions, and chemical impurities.

The main difference, and somewhat a significant difference, is in the lower efficiency rate compared to an inorganic semiconducting solar cell, such as the traditional silicon-based versions. With organic solar cells, the charge carrier mobility is low and this leads to a lower efficiency rating. In spite of this, and despite possessing an optical band gap of 2 electron volts (eV), organic solar cells are promising due to their affinity for chemical modification (via chemical synthesis techniques), their low manufacturing cost, and the potential for large-scale manufacture. These three reasons have led to the push for organic solar cells.

Inorganic semiconductors are better matched in their band gap energies to the solar spectrum, but have lower absorptivities than organic materials, requiring thicker absorbing layers, and high purities (and high costs) to insure efficient operation. Another key difference between OPVs and conventional inorganic solar cells is in the exciton binding energy. In both systems excitons (excited states) are formed upon photon absorption. In inorganic semiconductors the energy required to dissociate these excitons into charge carriers is quite small (a few millielectron volts, easily achieved at room temperature). In organic semiconductors the "exciton binding energy" can be as high as 0.5 eV or higher, requiring the formation of a D/A heterojunction to provide the internal electrochemical driving force for exciton dissociation to occur. Inorganic solar cells can be very efficient because a single inorganic material can be used with an exciton binding energy is negligible at room temperature. The physics of organic solar cells very different because the exciton is strongly bound. You need to have an acceptor and donor component with as much interface as possible between them in order that the formed excitons can quickly reach the interface to disassociate. Once the excitons have disassociated into two separated species, the electron and the hole, they must move efficiently toward the electrodes. Remember that the more you can order your material, in general, the better the mobility will be. The faster the electrons and the holes can move away from each other, the more efficient their separation will be.

B. Technology of Organic Solar Cell

In recent years, plastic polymers have been manipulated for designing transistors, conductors and other electrical components. The power conversion efficiency of Organic Solar Cells based on conjugated polymers has steadily increased through improved energy harvesting and enhanced exciton separation in improved device structures. The absorption of light in organic cells is done by the 'dye' which substitutes for the silicon in conventional cells. This light causes the dye molecules to get excited and release electrons that are converted to electrical energy. The use of chemicals called "dyes" for

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the conversion process has led to organic cells also being known as "Dye-Sensitized Solar Cell"(DSSC) or "Dye Solar Cell"(DSC). Compared to conventional silicon based photovoltaic cells, DSCs contain rather inexpensive materials and are quite simple to manufacture. DSCs consist of a nanoporous titanium oxide (TiO2) film covered with a monolayer of ruthenium polypyridyl complex dye, permeated with a redox electrolyte. The dye molecule is excited with incident light, and the excited electron is injected into the TiO2 conduction band. The dye molecule is quickly regenerated by the electrolyte tri-iodide (I3-) ion, which is oxidized to an (I3-) ion and then reduced back to I- at the counter electrode. The voltage generated corresponds to the difference between the Fermi level of the electrons in the TiO2 and the redox potential of the electrolyte. A schematic picture of the DSC structure and operating principle is shown in Figure 1.

C. Basic processes in organic solar cells

In general, for a successful organic photovoltaic cell five important processes have to be optimized to obtain a high conversion efficiency of solar energy into electrical energy:

1. Absorption of light and generation of excitons
2. Diffusion of excitons to an active interface
3. Charge separation
4. Charge transport
5. Charge collection

To create a working photovoltaic cell, the two photoactive materials are sandwiched between two (metallic) electrodes (of which one is transparent), to collect the photogenerated charges (see Figure 2). After the charge separation process, the charge carriers have to be transported to these electrodes without recombination. Finally, it is important that the charges can enter the external circuit at the electrodes without interface problems. Illumination of a donor material (in red) through a transparent electrode (ITO) results in the formation of an exciton (1). Subsequently, the exciton is transported by diffusion (2) to the interface between the donor material and an acceptor material (in blue). Electron is transferred to the acceptor material (A•-), leaving a hole at the donor material (D•+) (3). The photogenerated charged carriers are then transported (4) to and collected at opposite electrodes (5). A similar charge generation process can occur, when the acceptor is photoexcited instead of the donor. These phenomenon is shown in fig 3.

III. SOLAR RADIATION GEOMETRY

In solar radiation analysis, the following angles are useful:

Φ = latitude of location
δ = declination
ω = hour angle
n = monthly average of duration of actual sunshine hours(h)
N = monthly average of duration of a maximum possible sunshine hours (h)

The latitude Φ of a point or location is the angle made by the radial line joining the location to the centre of the earth with the projection of the line on the equatorial plane. It is the angular distance north or south of the equator measured from centre of the earth.

The declination δ is the angular distance of the sun's rays north (or south) of the equator.

The declination in degrees for any given day may be calculated from the approximate equation of Cooper (1969).

$$\delta(in\ degree) = 23.45 \sin\left[\frac{360}{365} * (284 + M)\right]$$

Where,

M is the day of the year, (e.g. June 21, 1988 is the 173th (31 + 29 + 31 + 30 + 31 + 21) day of 1988 i.e. M = 173)

The hour angle ω is equivalent to15° per hour. It is measured from noon based on the local solar time (LST) or local apparent time, being positive in the morning and negative in the afternoon. It is the angle measured in the earth's equatorial plane, between the projection of OP and the projection of a line from the centre of the sun to the centre of the earth.

ω can be expressed mathematically as:

$$\cos\omega = \sin\Phi\sin\delta/\cos\Phi\cos\delta$$
$$= \tan\Phi\tan\delta$$
$$\omega = \cos^{-1}(\tan\Phi \tan\delta)$$

Since 15° of the hour angle are equivalent to 1 hour, the day length (in hours)

$$N = \frac{2}{15}\omega = \frac{2}{15}\cos^{-1}(\tan\Phi \tan\delta)$$

Therefore, the length of the day N is a function of latitude and solar declination. The hour angle at sunrise or sunset on an inclined surface ω_{st} will be lesser than the value obtained, if the corresponding incidence angle comes out to be more than 90°. Thus for inclined surface having slope β has hour angle as

$$\omega_{st} = \cos^{-1}(\tan(\Phi - \beta) \tan\delta)$$

The corresponding day length (in hours) is then given by

$$N = \frac{2}{15}\cos^{-1}(\tan(\Phi - \beta) \tan\delta)$$

IV. METHODOLOGY

Solar energy application for thermal environment design the global radiation on a tilted surface is essential. The Liu and Jordan method is used in the present work [8]. The solar collector must be placed in tilted position with respect to the horizontal plane so that it collects maximum energy during the complete year. The tilt angle of the collector β is the angle between the horizontal plane and the plate collector surface. Liu and Jordan method have been used to estimate the total radiation both on horizontal and tilted surface [8][9]. It contains all the formula being used for the estimation. A linear relation was proposed by Angstrom's for computation of the average daily global radiation on horizontal surface.

$$H = Ho\,[a + b * n/N]$$

Where,

H = Total average daily global Radiation at horizontal surface
Ho = Extra-terrestrial solar radiation
a, b = Regression Constant
Ht = total average daily global radiation at tilted (β) surface

$$Ht = (H_b R_b + H_d R_d + HR_r)\ KW/m2$$

Where,

Hb = Average daily direct radiation

Hd = Average daily diffuse radiation

Rb = ratio of radiation on tilted Surface to radiationon horizontal surface

Rd = Conversion factor for diffuse radiation

Rr = conversion factor for ground reflected Radiation

The solar panel is fixed at angle β and employ the tracking mechanism to the base of the solar panel. This tracking results in increase in the average duration of hours for which we are getting sunlight. Thus as the position of sun changes the solar panel also has to be rotated so that it always faces the sun. The tracking is done by using fuzzy logic.

V. FIGURES

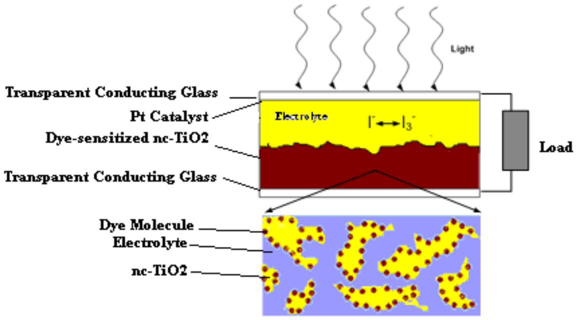

Figure 1: Schematic picture of the dye solar cell (on top) and its operating principle (below).

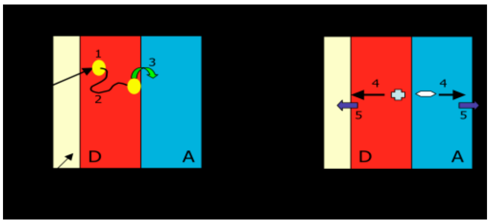

Figure 2: Schematic drawing of the working principle of an organic photovoltaic cell.

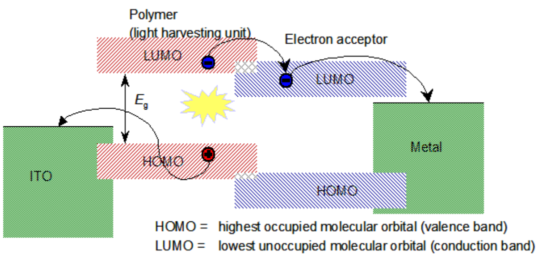

Figure 3: Schematic diagram shows the operation in organic solar cell

VI. CONCLUSION

Latest advances have shown a great potential for organic solar cells compared to conventional silicon cells. Their versatility in production methods, properties and applications looks very promising for the future of solar energy. Organic solar cells shows good promises in the development of low cost photovoltaic alternatives. A structured and systematic research are required in the field to successfully utilize the foreseen advantages of organic solar cells. From the estimation of solar radiation we conclude that the radiation on the tilted surface is more than that we get on the horizontal surface for the period when sun is not overhead. There is a significant increase in the output when tracking is done with fuzzy logic controller. The fuzzy logic based tracking results in an increase of about 25% in monthly average solar radiation. We propose to apply the solar organic cell in tracking system to enhance their conversion efficiency. It is expected that the solar organic cell could increase the efficiency, and consequently the conversion efficiency of thin film organic solar cells due to the localized surface plasmon based field enhancement effect, and meanwhile the dielectric shell could prevent the metal core becoming a new bulk recombination center of the light-induced excitons.

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