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Solar Tracker Mounted Battery Electric Vehicle

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Abstract

Solar photovoltaic energy conversion is a one-step conversion process which generates electrical energy from light energy. The explanation relies on ideas from quantum theory. Light is made up of packets of energy, called photons, whose energy depends only upon the frequency or color of the light. The energy of visible photons is sufficient to excite electrons, bound into solids, up to higher energy levels where they are freer to move. In a photovoltaic device, there is some built-in asymmetry which pulls the excited electrons away before they can relax, and feeds them to an external circuit. The extra energy of the excited electrons generates a potential difference, or electromotive force (e.m.f). This force drives the electrons through a load in the external circuit to do electrical work. A solar tracker is a device for orienting a solar photovoltaic panel or concentrating solar reflector or lens toward the sun. Solar cells on automobiles are mounted usually in a stationary manner where there is no degree of freedom and the angle of incidence keeps varying due to which maximum output cannot be extracted. The purpose of this project is to demonstrate the flexibility of this system by introducing the solar tracking mechanism onboard a vehicle so as to achieve maximum efficiency of photovoltaic conversion. The sun's position in the sky varies both with the seasons (elevation) and time of day as the sun moves across the sky. Along with these parameters, our application, being for non-stationary solar panels, will have to include orientations which would vary depending on the direction of motion of the vehicle, direction in which it is parked, etc. Solar powered equipment works best when pointed at or near the sun, so a solar tracker can increase the effectiveness of such equipment over any fixed position, at the cost of additional system complexity.

1. Introduction

Photovoltaic's use the principle of direct conversion of light into electricity at the atomic level Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured and allowed to flow through an external circuit, a resultant electric current is produced that can be used for various purposes.

This project presents the practical utilization of the solar energy by using solar tracking system in automobiles. It is seen that fixed type of photovoltaics is used in vehicles using solar cell arrangement till date. This setup is highly disadvantageous due to the fact that the complete utilization of incident light is not possible.

Hence by providing a solar tracking mechanism along with the solar panel unit, the overall efficiency of the system can be enhanced. In this paper, we discuss the various possibilities and options that open up, if we are to incorporate a solar tracking mechanism onto a battery electric solar powered vehicle.

2. Brief History of the Solar Cell

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The photovoltaic effect was first reported by Edmund Becquerel in 1839 when he found that certain materials would produce small amounts of electric current when exposed to light. He observed that the action of light on a silver coated platinum electrode immersed in electrolyte produced an electric current. In 1905, Albert Einstein described the nature of light and the photoelectric effect on which photovoltaic technology is based, for which he later won a Nobel Prize in physics. Forty years later the first solid state photovoltaic devices were constructed by workers investigating the recently discovered photoconductivity of selenium. In 1876 William Adams and Richard Day found that a photocurrent could be produced in a sample of selenium when contacted by two heated platinum contacts. The photovoltaic action of the selenium differed from its photoconductive action in that a current was produced spontaneously by the action of light. No external power supply was needed. In this early photovoltaic device, a rectifying junction had been formed between the semiconductor and the metal contact. In 1894, Charles Fritts prepared what was probably the first large area solar cell by pressing a layer of selenium between gold and another metal. In the following years photovoltaic effects were observed in copper-copper oxide thin film structures, in lead sulphide and thallium sulphide. These early cells were thin film Schottky barrier devices, where a semitransparent layer of metal deposited on top of the semiconductor provided both the asymmetric electronic junction, which is necessary for photovoltaic action and access to the junction for the incident light. The photovoltaic effect of structures like this was related to the existence of a barrier to current flow at one of the semiconductor-metal interfaces (i.e., rectifying action) by Goldman and Brodsky in 1914. Later, during the 1930s, the theory of metal semiconductor barrier layers was developed by Walter Schottky, Neville Mott and others.

3. Working of Complete arrangement

3.1. Solar cell

A photovoltaic cell consists of a light absorbing material which is connected to an external circuit in an asymmetric manner. Charge carriers are generated in the material by the absorption of photons of light, and are driven towards one or other of the contacts by the built-in spatial asymmetry. This light driven charge separation establishes a photo voltage at open circuit, and generates a photocurrent at short circuit. When a load is connected to the external circuit, the cell produces both current and voltage and can do electrical work.

The size of the current generated by the cell in short circuit depends upon the intensity and the energy spectrum of the incident light. Photocurrent is related to incident spectrum by the quantum efficiency of the cell, which is the probability of generating an electron per incident photon as a function of photon energy. When a load is present, a potential difference is created between the terminals of the cell and this drives a current, usually called the dark current, in the opposite direction to the photocurrent. As the load resistance is increased, the potential difference increases and the net current decreases until the photocurrent and dark current exactly cancel out. The potential difference at this point is called the open circuit voltage. At some point before Voc is reached, the current-voltage product is maximum. This is the maximum power point and the cell should be operated with a load resistance which corresponds to this point.

The solar cell can be modeled as a current generator in parallel with an ideal diode, and the current-voltage characteristic given by the ideal diode equation. In real cells, the behavior is degraded by the presence of series and parallel resistances.

3.2. Solar tracker unit

The tracking circuit mainly works taking the inputs from the sensor units and giving signals to the microcontroller which in turn gives the pulses to drive the motor. The sensing units in this circuit are light depending resistors (LDRs) whose resistance varies proportional to the brightness of the light. The microcontroller generates pulses to run the motor depending on the program. The motor used is a geared DC motor. This stepper motor takes the input from the microcontroller and turns accordingly. The practical utilization of the solar energy normally depends on detailed irradiation knowledge of the inclined planes. The choice of the favorable collector orientation helps to reduce the cost by increasing the radiant flux per unit collector area, so enabling a greater energy collection efficacy to be achieved per unit of investment.

When exposure of any site used for harnessing of solar energy photo voltaic ally allows the most favorable orientations tend to be south facing in the northern hemisphere and north facing in the southern hemisphere. However there are some climates where the afternoons are cloudier than forenoons, in these cases the true north-south orientation rule may be inappropriate. The appropriate choice of the collector

tilt and collector orientation is always an important decision which is influenced by the latitude.

4. Optimal Tilt Angle of Solar Collector [1]

An apparatus consisting of three solar cells in series, glued to a plastic plane was developed and studied. The plane had an axe and was able to pivot through two rubber grommet-holes drilled in two vertical triangles. A red needle was glued to the end of one side of the axel, as the cells were rotated the needle would rotate with it, always denoting the exact angle of incidence. This apparatus was secured to a solid base, and around the apparatus was placed a tall black column. The purpose of the column was to block most (if not all) ambient light from hitting the solar cells. The leads from the solar cells were extended through a small hole on the bottom of the column and were then attached to the multi-meter according to respective measurement. For voltage: the leads from the cells were connected directly with the leads of the multi meter. For measuring current: one lead of the solar cell was connected to a small light bulb (11.1 Ω), the other lead of the light bulb was connected to the multi meter, the other lead from the solar cells was connected to the multi meter. After the apparatus was completed the following procedure was followed to collect data:

1. On a cloudless day] an area with open access to the Sun was selected and the column with the solar cells inside was secured to the ground facing directly toward the Sun.
2. The column (attached to its base) was then shifted around until the shadow of the column disappeared.
3. The cells were aligned to 0 degrees (perpendicular to the Sun's rays) according to the protractor and the leads from the cells were clipped to the multi-meter.
4. The temperature and time of day was recorded before data was collected.
5. Voltage and current readings were collected at 1 degree angle increments between 0-90 degrees. Note: Actual readings were taken from 0 to 100 degrees and additional points taken at 135 and 180 degrees.

5. Components and Operation

5.1 The 555 Integrated Circuit [2]

The 555 integrated circuit is an extremely versatile timer that can be used in many different applications. This IC is a monolithic timing circuit that is a highly stable controller capable of producing accurate time delays or oscillations. Additional terminals are producing are provided for triggering or resetting if desires.

Timer operation

In the time delay mode of resistance and a capacitor, for stable operation as an oscillator, the free running frequency and the duty cycle are both accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output structure can source or sink up to 200ma or drive TTL Circuits. This integrated circuit contains nearly 25 transistor, a diode or two, and more than 10 resistors. Obviously, if you built this IC from separate components, it would be many, many times larger than on a monolithic chip. The 555 timer offers timing from microseconds through hours and operates in both a stable and constable modes. It has an adjustable duty cycle, and the output can drive TTL devices. Its output can operate in normally on and normally off modes and the IC offers a frequency stability of 0.005% per degrees centigrade.
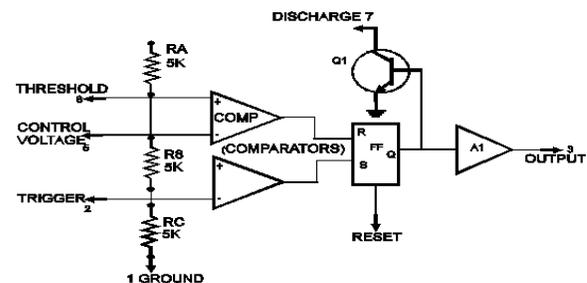

Fig: 1.

Applications for the 555 chip include precision timing, pulse generation, pulse width modulation, pulse position modulation, sequential timing, and missing pulse detection.

5.2. Relay [2]

Relay is a common, simple application of electromagnetism. It uses an electromagnet made from an iron rod wound with hundreds of fine copper wire. When electricity is applied to the wire, the rod becomes magnetic. A movable contact arm above the rod is then pulled toward the rod until it closes a switch contact. When the electricity is removed, a small spring pulls the contract arm away from the rod until it closes a second switch contact. By means of relay, a current circuit can be broken or closed in one circuit as a result of a current in another circuit.

Relays can have several poles and contacts. The types of contacts could be normally open and normally closed. One closure of the relay can turn on the same normally open contacts; can turn off the other normally closed contacts. Relay requires a current through their coils, for which a voltage is applied. This voltage for a relay can be D.C. low voltages up to 24V or could be 240V a.c.
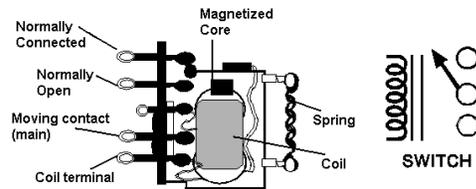

Fig: 2.

6. Light Detecting Resistance LDR [2]

A photo-resistor or light dependent resistor is resistor whose resistance decreases with increasing incident light intensity; in other words, it exhibits photoconductivity. A photo-resistor is made of a high resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance. LDRs or Light Dependent Resistors are very useful especially in light/dark sensor circuits. Normally the resistance of an LDR is very high, sometimes as high as 1000 000 ohms, but when they are illuminated with light resistance drops dramatically.

6.1. Procedure

The setup consists of solar cells arranged to a panel mounted on a single axis rotor bed. The panel has LDR sensors that detect the presence of light and the circuitry is wired in such a way as to orient the panel towards the sun. The model presented here is a single axis tracker that has a limited degree of freedom as shown below.
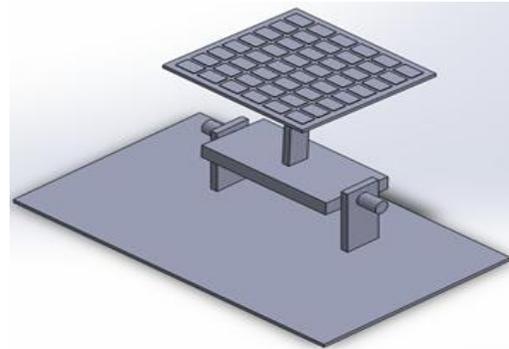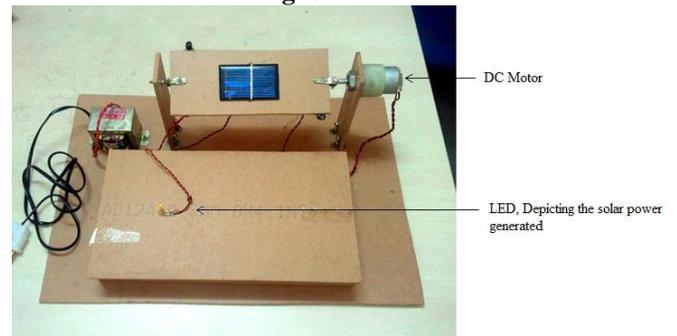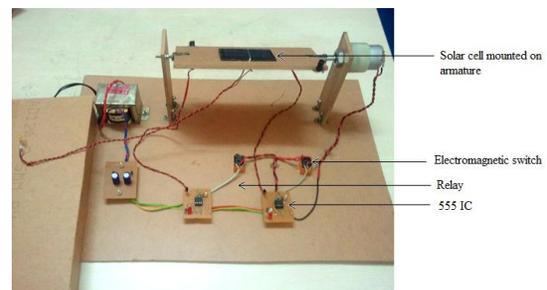

Fig: 3.

Fig: 4.

Fig: 5.

The proposed project aims at a multi-axial tracker that has a number of degrees of freedom. The tracker is initially mounted onto the roof of the vehicle and fixed by bolting it or by any other mechanism. The entire tracker unit is self-operational, where the power to run the servo motors that lets the panel rotate along the x, y and z axii, comes directly from the solar cell itself. A simple plug in to the vehicle battery is provided that electrically connects the solar cells to the vehicle and powers it. During running condition, the tracker assumes the low drag aerodynamic position where it aligns itself parallel to the roof. Though the tracker is nonfunctional, the solar panel functions depending on the amount of sunlight received and the angle at which it is incident, giving an output current which may or may not be the maximum value. But as soon

as the vehicle is parked in the sunlight, the panel automatically detects the position of the sun and tracks it by orienting itself with the smallest possible incident angle and the maximum power is derived, no matter what direction the car is parked.

This system can be integrated most effectively with the existing battery electric vehicles and can act as a backup power source in areas where electric charging outlets are unavailable. The various orientations of the panel are shown below. The panel can be pitched about the x-axis, rolled about z-axis and yawed about the y axis as shown in the models below. By providing a ball and socket joint, the number degrees of freedom can be further increased based on the necessity.
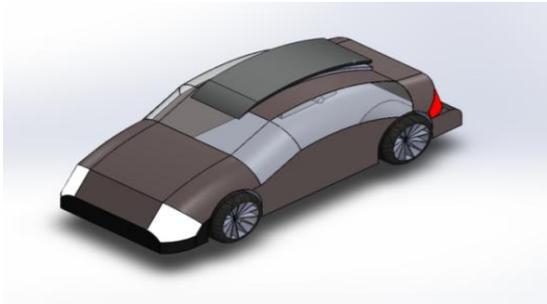

Fig: 6. Tracker in normal drive mode
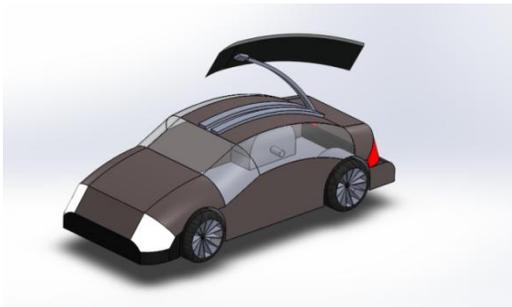

Fig: 7. Tracker pitched about x-axis

Fig: 8. Tracker pitched about x-axis and rolled about z-axis
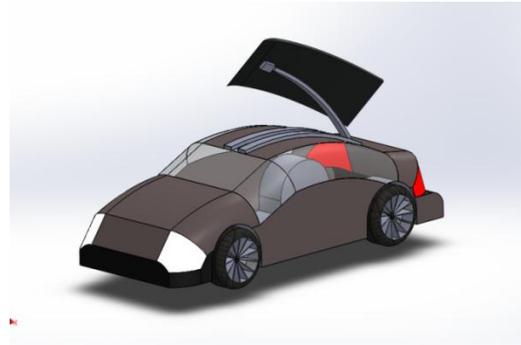

Fig: 9. Tracker pitched about x-axis, rolled about z-axis & yawed about y-axis

7. Result and Graphs [3]

The following graphs and table show the results of the experiment: voltage & current vs. angle of incidence, current & power vs. angle of incidence, power & power error vs. angle of incidence, and finally voltage drop vs. angle of incidence. Data includes the numerical data of angle, voltage, voltage ± error, current, current ± error, power, power error and power ± error. Errors for voltage measurements were constant, as were errors for current measurements, both are based on specs provided by *Fluke*, the manufacturer of our multimeter. The results of the experiment were very close to what we expected. The voltage vs. angle was very linear until it reached an expected threshold, after which a steep decline in voltage was observed. Also expected was a more predictable current output. It was thought that the current and voltage would behave similarly, but they did not follow the same trend. After calculating the power, it was apparent that the power graph and
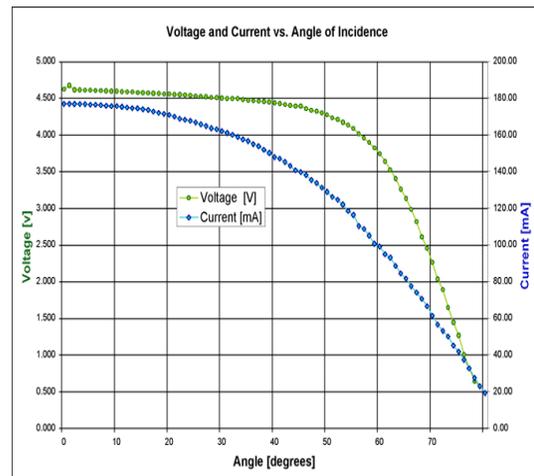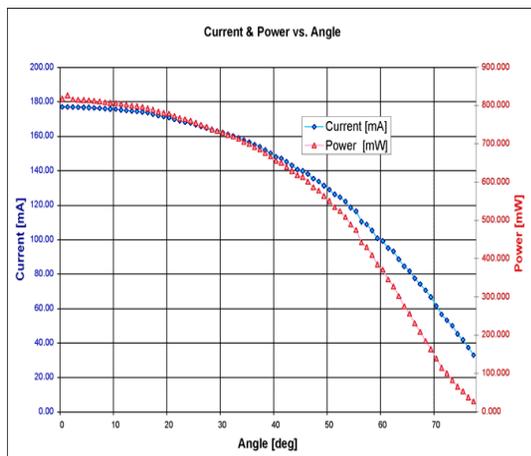

Fig: 10. Graph 1[3]
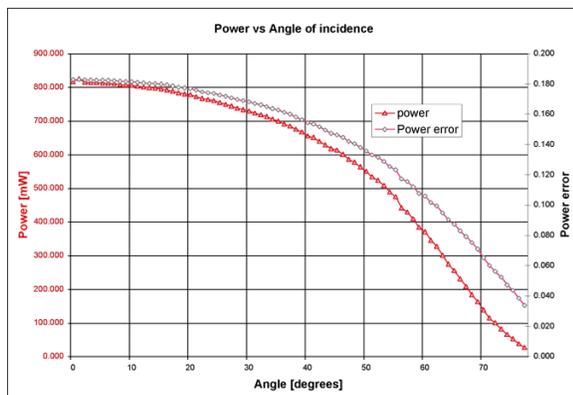
Fig: 11. Graph 2[3]

Fig: 12. Graph 3[3]

when superimposed one could see a distinct similarity. This was expected however, since the current [range] dominates voltage [range] in the power equation. When the power equation is graphed with the calculated power error, the graph is what we expected. The power graph drops off slightly faster than the graph of the power-error calculation. This is because even at very low power levels there is still inherent error in the power calculation. The highest power-calculation-error exists at the lowest power values, for this reason it is vital that we used the RSS method of error analysis. Simply multiplying the %error Voltage with the %error current would lead to a false account of error (error would come out to high.) The significance of these graphs is very important to the understanding of solar cells. From the results, it shows that voltage does not change dramatically until an angle of incidence of about 45° is reached, after which voltage drops rapidly. The current and power-response to angle do not have a threshold and are non-linear.

8. Conclusion

The voltage output of a solar panel is approximately linear until a certain angular threshold is reached, in the experiment conducted this was found to be approximately 45°, after which voltage drops significantly. Current output fits a cosine trend: $I = Imax * COS\ (\theta)$ .Power roughly fits the same trend: $P = Pmax * COS\ (\theta)$.

So by aligning the panel approximately normal to the incident light during the operation of the system, we are able to obtain the maximum power output.

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