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Solar Tracking System: More Efficient Use of Solar Panels

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***Abstract*—**This paper shows the potential system benefits of simple tracking solar system using a stepper motor and light sensor. This method is increasing power collection efficiency by developing a device that tracks the sun to keep the panel at a right angle to its rays. A solar tracking system is designed, implemented and experimentally tested. The design details and the experimental results are shown.

***Keywords*—**Renewable Energy, Power Optimization.

I. Introduction

EXTRACTING useable electricity from the sun was made possible by the discovery of the photoelectric mechanism and subsequent development of the solar cell – a semi-conductive material that converts visible light into a direct current. By using solar arrays, a series of solar cells electrically connected, a DC voltage is generated which can be physically used on a load. Solar arrays or panels are being used increasingly as efficiencies reach higher levels, and are especially popular in remote areas where placement of electricity lines is not economically viable.

This alternative power source is continuously achieving greater popularity especially since the realisation of fossil fuel's shortcomings. Renewable energy in the form of electricity has been in use to some degree as long as 75 or 100 years ago. Sources such as Solar, Wind, Hydro and Geo-thermal have all been utilised with varying levels of success. The most widely used are hydro and wind power, with solar power being moderately used worldwide. This can be attributed to the relatively high cost of solar cells and their low conversion efficiency. Solar power is being heavily researched, and solar energy costs have now reached within a few cents per kW/h of other forms of electricity generation, and will drop further with new technologies such as titanium-oxide cells. With a peak laboratory efficiency of 32% and average efficiency of 15-20%[1-4], it is necessary to recover as much energy as possible from a solar power system.

This includes reducing inverter losses, storage losses, and light gathering losses. Light gathering is dependent on the angle of incidence of the light source providing power (i.e. the sun) to the solar cell's surface, and the closer to perpendicular, the greater the power [1-7]. If a flat solar panel is mounted on level ground, it is obvious that over the course of the day the sunlight will have an angle of incidence close to 90°in the morning and the evening. At such an angle, the light gathering ability of the cell is essentially zero, resulting in no output. As the day progresses to midday, the angle of incidence approaches 0°, causing an steady increase in power until at the point where the light incident on the panel is completely perpendicular, and maximum power is achieved.

As the day continues toward dusk, the reverse happens, and the increasing angle causes the power to decrease again toward minimum again.

From this background, we see the need to maintain the maximum power output from the panel by maintaining an angle of incidence as close to 0° as possible. By tilting the solar panel to continuously face the sun, this can be achieved. This process of sensing and following the position of the sun is known as Solar Tracking. It was resolved that real-time tracking would be necessary to follow the sun effectively, so that no external data would be required in operation.

II. The Sensing Element and Signal Processing

Many different methods have been proposed and used to track the position of the sun. The simplest of all uses an LDR – a Light Dependent Resistor to detect light intensity changes on the surface of the resistor. Other methods, such as that published by Jeff Damm in 'Home Power' [8], use two phototransistors covered with a small plate to act as a shield to sunlight, as shown in Fig. 1.

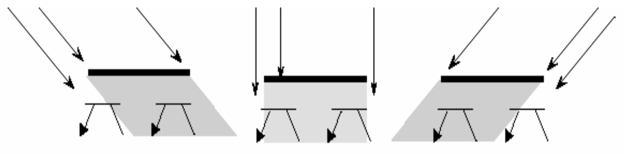

Fig. 1 Alternative solar tracking method

When morning arrives, the tracker is in state A from the previous day. The left phototransistor is turned on, causing a signal to turn the motor continuously until the shadow from the plate returns the tracker to state B. As the day slowly progresses, state C is reached shortly, turning on the right phototransistor. The motor turns until state B is reached again, and the cycle continues until the end of the day, or until the minimum detectable light level is reached.

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The problem with a design like this is that phototransistors have a narrow range of sensitivity, once they have been set up in a circuit under set bias conditions. It was because of this fact that solar cells themselves were chosen to be the sensing devices. They provide an excellent mechanism in light intensity detection – because they are sensitive to varying light and provide a near-linear voltage range that can be used to an advantage in determining the present declination or angle to the sun. As a result, a simple triangular set-up was proposed, with the two solar cells facing opposite directions, as shown in Fig. 2.

In its rest position, the solar cells both receive an equal amount of sunlight, as the angle of incidence, although not 90°, is equal in both cases as seen in Fig. 3.

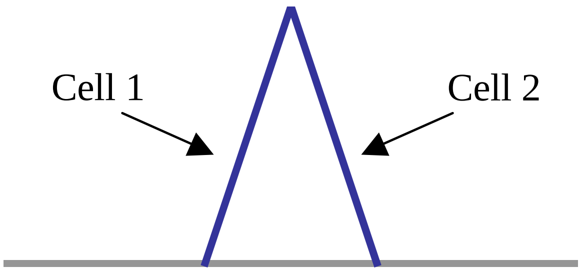

Fig. 2 Set-up of solar reference cells

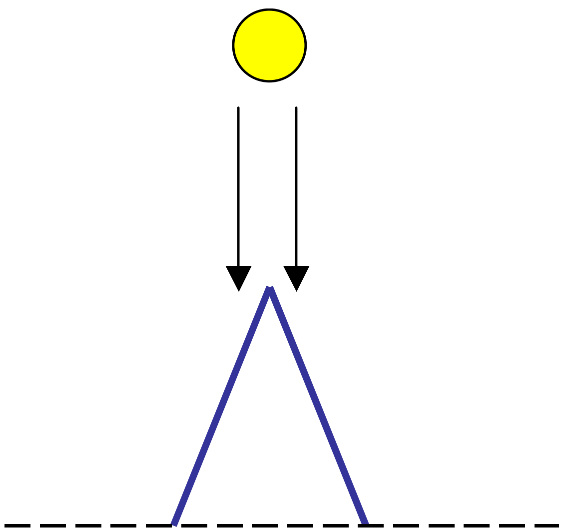

Fig. 3 Solar reference cells at rest position

It can be seen in Fig. 4 that as the sun moves in the sky, assuming that the solar tracker has not yet moved, the angle of incidence of light to the reference panels will cause more light to fall on one cell than the other.

This will obviously cause a voltage difference, where the cell that is facing the sun will have higher potential than the other. This phenomenon will result in a detectable signal at each cell, which can be processed by a suitable circuit.

III. A Prototype Solar Tracker

The final stage involved coupling the circuitry to the motor and mounting it onto the bracket. The final product is seen complete in Fig. 5. It has a Solarex 9W solar array made of polycrystalline silicon mounted on the flanges, which was borrowed from the tech officers.

Quite simply having two test subjects carried out testing. The first scenario involved removing the panel from the tracker and laying it in a flat orientation. The output was connected to a load that would dissipate 9W that would match the panel's rating. 9W at 12V corresponds to a current of 0.75A, so by Ohm's law; a load resistance was calculated as being 16Ω. A 15Ω 50W resistor was the closest value found and was connected to the panel. The tracking device still requires power, but a 12V battery that is connected in a charging arrangement with the solar panel supplies it. The voltage across and current through the load was monitored using two separate multimeters, and was recorded every half-hour on a clear day into an Excel spreadsheet. The readings were taken on a span of days that possessed similar conditions including no cloud cover. The readings are shown below in a graph generated by Excel in Fig. 6.

Fig. 5 A prototype solar tracker

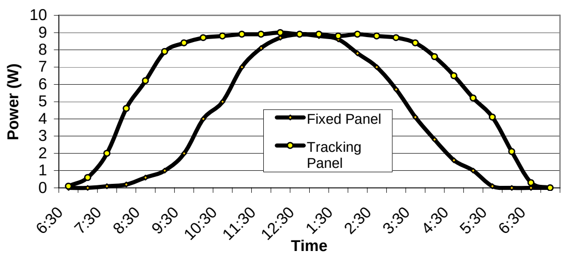

Fig. 6 Experimental results of power increase for tracked panel

It is possible to calculate a percentage increase and an average increase by writing the appropriate calculations in excel. It was found that in this case, the fixed panel provided an average of 39% of its 9W, or 3.51W, calculated over a 12-hour period. By contrast, the tracked solar panel achieved an overall 71% output, or 6.3W over the same time frame. At the earlier and later hours, the power increase over the fixed panel reached up to 400%. This amounts to an average 30% increase in power simply by maintaining the solar panel as perpendicular as possible to the sun.

To ensure that power was not being wasted, the device itself was also monitored for current drawn to power itself. When the device was at rest, an ammeter was placed in series with the battery. The total current at 12V was measured as only 4mA, which corresponded to a power dissipation of 48mW under no load.

IV. Discussion

A solar tracker was proposed, designed and constructed. The final design was successful, in that it achieved an overall power collection efficiency increase from only 39% for a fixed panel to over 70% for the same panel on the tracking device. In terms of real value, this means that the overall cost of a system can be reduced significantly, considering that much more power can be supplied by the solar array coupled to a solar tracking device. By extracting more power from the same solar panel, the cost per watt is decreased, thereby rendering solar power much more cost-effective than previously achieved using fixed solar panels.

The high outlay in a solar tracking system has been a factor that discouraged tracking as a means of increasing overall solar efficiency. Many commercial units cost in excess of US$2000 for a unit that can track the sun while bearing a panel of considerable weight. The device presented in this thesis is capable of supporting a load of at least 8kg, the average weight of a 75W solar panel, owing to its simple construction and the high torque capabilities of the motor. The parts used for this device were also extremely low-cost, with the total value using parts found from 'scrap' sources being a total of about A$30, including all electronic components and solar reference cells. The geared support was removed from an old security camera, the stepping motor from an old printer, and all other parts, excluding the 9W solar panel, were sourced from various scrap items. However, if all these parts would have to be purchased, the cost would be projected at no more than A$100.

A single axis tracker such as the one made offers a great power increase over a fixed solar panel, but a two-axis tracker would provide more power still. This could be a subject for further development.

Solar tracking is by far the easiest method to increase overall efficiency of a solar power system for use by domestic or commercial users. By utilising this simple design, it is possible for an individual to construct the device themselves.

V. Conclusion

A solar tracker is designed employing the new principle of using small solar cells to function as self-adjusting light sensors, providing a variable indication of their relative angle to the sun by detecting their voltage output. By using this method, the solar tracker was successful in maintaining a solar array at a sufficiently perpendicular angle to the sun. The power increase gained over a fixed horizontal array was in excess of 30%.

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Fig. 4 Solar reference cells at a significant angle to the sun