System Tests and Simulations for a Power Efficient Portable Solar Panel

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Abstract: This paper is concerned with a portable automatic solar panel, mounted on a mobile trailer. Our work approaches the efficiency of the solar panel with respect to the incident angle of the sunshine on the panel. The work pointed out the benefits of higher output power generated by a mobile solar tracking device used for solar panels, compared to fixed PV systems.

Keywords: solar panel, test, simulations, portable system

1 Introduction

This paper is concerned with a portable automatic solar panel, mounted on a mobile trailer. The benefits of a mobile solar panel versus one mounted in a fixed position are highlighted. The paper focuses mostly on the efficiency of the solar panel, in relation to the sunlight angle with respect to the panel surface [9, 10].The results of the analysis performed demonstrate the higher efficiency of the panel mounted on a sun tracking device with quantifiable differences reported in the paper. This automatic solar panel on a trailer, it's mobile, so one can take it everywhere he needs and after stopping the solar panel turns itself after the sun for best efficiency. Being mobile, the position of the solar panel differs a lot, so it is important that the panel rotates after the sun in order to get a satisfying power output.

This paper approaches the efficiency of the solar panel with respect to the incident angle of the sunshine on the panel.

The analysis performed quantifies the performance difference between a fixed position PV panel and one linked to a sun tracking device, thus demonstrating that they are noticeable. The research work led to the design of a highly efficient, portable and cheap automated solar panel power supply system, capable of providing the energy needed to sustain the automatic system and some small power consumers [1, 2].

Several software packages have been used in this project. LabView and Solidworks were used for the simulation, while Arduino IDE and Fritzing (used for sketching the circuit diagram) were used for designing the schematic and programming the Arduino microcontroller board; Lab View software is useful for any measurement or control system development [7, 8]. This visual programming language is easy to use and can program an Arduino board or even motions in Solidworks.

The current work has confirmed that a fixed solar panel is characterized by big variations of the power output delivered during a day and also during different seasons of a year. It was also confirmed that a solar tracking device increases the average output power delivered during a day. A solar tracking device is normally cost-effective only for larger installations, due to the added cost of the tracking systems. For this reason, a cheaper solar tracking device was proposed as prototype [3, 4].

2 Pretest using a mobile Panel

It is known that the angle of incidence of sunlight impacts the efficiency of a solar panel a lot. That's why, the first pre-test we made, was to find out how different incidence angle of sunlight on a solar panel impacts the efficiency of it.

The independent variable is the angle of the solar panel while the dependent variable is the power output.

We chose 7 angles for this test: 90° to sunlight, 75° to sunlight, 60° to sunlight, 45° to sunlight, 30° to sunlight, 15° to sunlight, 0° to sunlight. First, the pretest is made outdoors at noon when the sun is up on a clear day. For measuring the current and voltage we used a Digital Multimeter, DT-838.

The measurements it is made by adjusting the inclination angle until it reaches the position corresponding to the highest generated voltage (while measuring the voltage generated by the panel). The maximum power is calculated with the equation 1. As soon as a load is connected to the solar panel, the power P_{out} will decrease.

$$P_{out} = I_{sc} \cdot V_{oc}, \qquad (1)$$

where P_{out} is the maximum output power, I_{SC} is the short-circuit current, V_{oc} is the open-circuit voltage.

As we can see in Table I and Table II, we made two measurements at 13:00 PM and 13:10 PM, for better results.

TABLE I. THE MEASUREMENT 1

Measurement 1				
Angle[°]	U[V]	R[Ω]	I[A]	P[W]
0	12.460	500000	0.249	3.105
15	18.400	500000	0.368	6.771
30	18.560	500000	0.371	6.889
45	18.680	500000	0.374	6.979
60	18.750	500000	0.375	7.031
75	18.820	500000	0.376	7.084
90	18.900	500000	0.378	7.144

TABLE II. THE MEASUREMENT 2

Measurement 2				
Angle[°]	U[V]	R[Ω]	I[A]	P[W]
0	16.500	500000	0.330	5.445
15	18.320	500000	0.366	6.712
30	18.550	500000	0.371	6.882
45	18.640	500000	0.373	6.949
60	18.710	500000	0.374	7.001
75	18.790	500000	0.376	7.061
90	18.870	500000	0.377	7.122

The results shown in the tables above and the chart results of Figure 1, confirm the hypothesis that the solar panel has the highest power output when it is perpendicular to the sunlight and declines as the angle decreases.

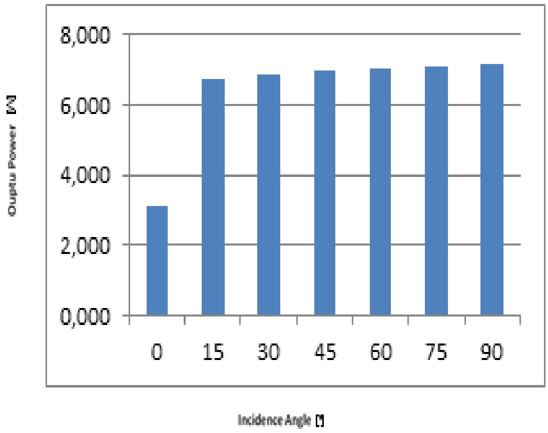

Fig. 1. The Output power using a mobile panel

3 Pretest using a fixed Panel

While the first pretest we made was to find out how different incidence angle of sunlight on a solar panel impacts the efficiency of it, our second pretest we made us a fixed Panel. The pretests consist in measurements of the power output during a day when the solar panel is south oriented and positioned at an angle of 45°.

The measurements are taken from 8 o'clock to 20 o'clock, at 15 minutes interval. Our pretest will show that the power output is small in the morning, reaches a peak at around 2 PM and decreases afterwards. Hypothesis was right, the power increases, reaches a peak and decreases during a day if the solar panel is fixed on a position facing south at a 45° angle (Fig. 2).

It can be noticed that the power output varies significantly during a day; in the morning and evening, because the panel is fixed, the sunlight does not fall perpendicular to the solar panel, thus this is a case of reduced energy output.

The results of the two pretests show that the incident angle is very important and that the panel should always be oriented towards the sun.

A small difference in the incidence angle is already visible in the power output. Later, another test will be performed when the solar panel will track the sun, aiming to quantify the differences between a solar tracking device and a fixed mounted solar panel.

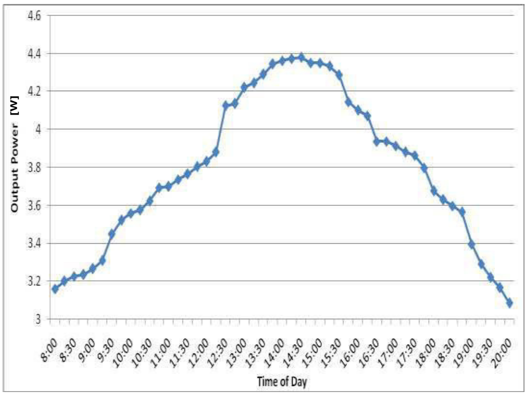

Fig. 2. . The Output power during a day, using a fixed solar panel

4 Simulations

For the simulation we made a simple project where we added the Solidworks assembly and the axis needed for the motion study. Each axis was connected to a "Motion-Motor" attached in Solidworks Simulation.

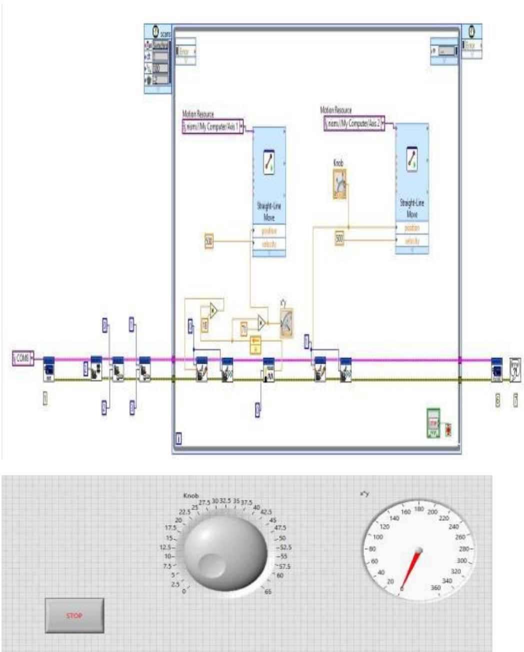

Fig. 3. The LabView back-end and LabView front-end

We used the LabView software for connecting the simulation with Arduino and Solidworks software was used for the 3D model. In order to see the movement of the panel and to determine how to build the trailer for the panel the 3D simulation was made.

As we can see in the following images, in Figure 3 it is shown the front-end and the back-end VI. We used for simulations Solidworks software to create a 3D model of the trailer containing the solar panel that we will build, in order to study the design and the motion of the panel. With help of Solidworks we made the file with all the parameters needed in order to build the physical version of it.

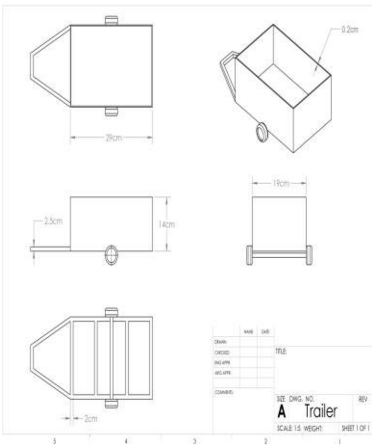

Fig. 4. The model of the Trailer

The Model is a basic one, it could be developed a lot more in Solidworks, but since the simulation was not my main concern, a simple model for the simulation was enough to test it and see if it would work. (Fig. 4).The motion in Solidworks is made through LabView, changing the position of the potentiometer or the position of the knob moves the position of the Servo Motors in the Simulation and also of those connected to the Arduino. With the cosimulation of Arduino, LabView and Solidworks we can easily make a 3D version of a bigger project and simulate it in Labview, controlled directly from Labview or from Arduino (Fig. 4).

The LabView software is useful for many measurement or control system developments [7].This visual programming language can program an Arduino board or even motions in Solidworks and is also easy to use. So we are using LabView because it's the medium from which we can control the Microcontroller and see the movements live in 3D Solidworks motion analysis (Fig. 5).

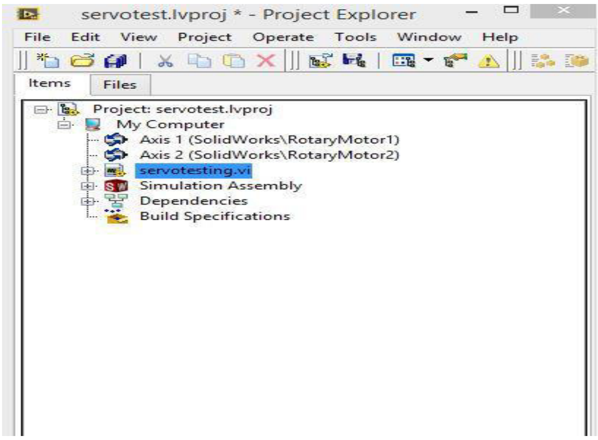

Fig. 5. The LabView Project

The Arduino IDE and Fritzing (used for sketching the circuit diagram) were used for designing the schematic and programming the Arduino microcontroller board. "Arduino is an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. Arduino projects can be stand-alone, or they can communicate with software running on the computer Arduino it is simple to use, cheap and very flexible.

In Figure 6 it is shown the Servo and Photocells connection to Arduino

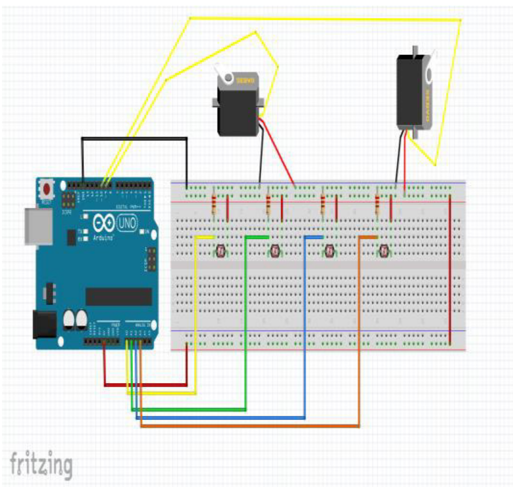

Fig. 6. Photocells and Servo connection to Arduino

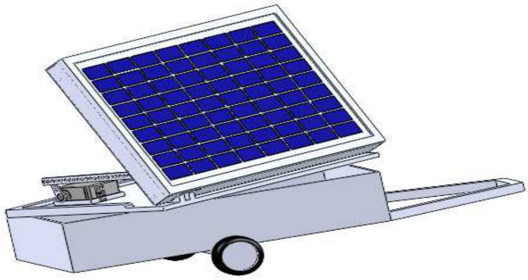

Fig. 7. The Solidworks 3D model of the Trailer

The simulation provided helpful information about the movement of all the elements in the system and about the difference between the angle of the servo and the actual angle in which the solar panel will be positioned (Fig. 7). Because the servo is not exactly at the joint, the angle of the panel is smaller than the angle of the servo. A 90° angle on the servo will be approximately equivalent to a 75° angle on the solar panel.

5 Real System Building

After the simulation, the building of the real model started. First the upper part was done, the Solar Panel, was attached with two hitches on one side of a board having the size of the panel. On the other side it was free so that the tilt of the panel could be possible. Unlike the simulation, the servo motor was mounted near the hitches and not on the far side of the hitches for easier lifting of the panel. The Analog Servo - HD - 1501MG has been used for the tilt movement because it is more powerful than the other Servo used in this project and could tilt the Solar Panel unlike the Analog Servo Power HD Standard 6001HB that has been used for the rotation of the board with the Solar Panel. Another difference between the 2 Servos is that the first one has a slightly different mechanism, which remains in the position it was left, even when the current is turned off. That means that after the panel is inclined to an angle (different than 0), the panel will not return to its initial position, but will stay in the last position it found itself when the power was turned off.

After finishing the tilt movement, the upper part of the model was almost done, another 4 holes where made where the Photo resistors where put for the automation of the panel.

The second part of building the model was the trailer inside. The storage battery was placed inside, as well as the Arduino with all the wirings. The battery had quite a big housing for my model, where it had 1 USB output, two 12V outputs, 1

LED, 1 Push-Button (ON/OFF) and 1 input from the solar panel. In order to fit all this inside, I disassembled the housing, fixed the battery into the front part of the trailer in the middle, and drilled holes in order to have the Push-Button, the LED and the two 12V outputs on the outside.

The USB will be used for the Arduino, so together with the input hole, I mounted them inside. If we analyze the Fig. 8 we see that the differences between the power outputs during

a day with a solar tracker system are not so big and we notice that the average power output during the test day with the solar tracker is 4.390. The solar panel reaches the peak output value early and keeps it constant for a longer period of time before decreasing again.

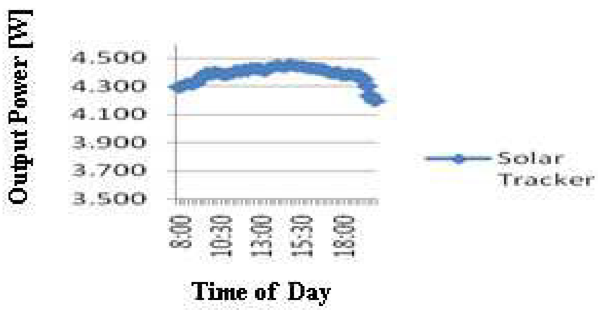

Fig. 8. Power output during a day using a mobile panel

It is seen that the power output is constant during a day with the solar tracker system, while with a fixed panel the power output is low in the morning, increases until midday and drops afterward (Fig. 9).

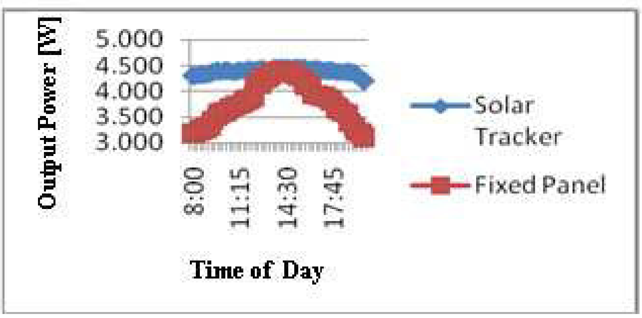

Fig. 9. Power output between a fixed and a portable panel

The tests were carried out in two different days, with the test for the fixed panel being done on a sunnier day. The real gain achieved through the use of the mobile system is expected to be higher in reality, because of the different weather conditions during the two test days. As it can be seen in Fig. 9, the highest differences in the power generated as part of the two tests are in the morning and afternoon, due to the fact that the angle at which the sunlight aligns with the fixed solar panel is not optimized in the morning, thus losing a significant amount of energy. In the morning, using a solar tracker, the solar panel is turned towards the sun, thus increasing the power output in the early hours of the day. The peak value is reached faster and it is then maintained for a couple of hours, while in the afternoon, the output power decreases slower, increasing the average output power during a day. This difference increases if the fixed panel is set at an average incidence angle between summer and winter. The tests performed and presented in our work were done in June and July.

We will continue our research to have more data to confirm that the portable solar panel is profitable either for low solar productivity (winter) or for high solar productivity. Thus, in order to achieve a more complete research and some will yield results that belong to different seasons in a year.

Conclusions

Our paper approaches the efficiency of the solar panel with respect to the incident angle of the sunshine on the panel [10].The present work has confirmed that a fixed solar panel is characterized by big variations of the power output delivered during different seasons of a year and during a day also. Solar cell efficiency may be broken down into reflectance efficiency, thermodynamic efficiency, charge carrier separation efficiency and conductive efficiency. The overall efficiency is the product of these individual metrics. The power conversion efficiency of a solar cell is a parameter which is defined by the fraction of incident power converted into electricity. A solar cell has a voltage dependent efficiency curve, temperature coefficients, and allowable shadow angles.

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