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Enhancement of power generated by solar panels using reflected sunlight

Shounaq Pandit, Hemant Pardeshi, Yashraj Shinde, Suhel Sanade

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Abstract - *The enhancement of energy generated using solar photovoltaic panels in a limited space is important in urban areas due to increased land cost in the recent years. Although there exist different procedures, technologies and methodologies to focus the sunlight on solar panels, we have suggested a new approach to enhance the energy generation from the photovoltaic panels, i.e., by keeping two solar panels facing each other to make use of the sunlight reflected off panels. Furthermore, inclusion of a self-cleaning technology for solar panel setup can promote efficiency in terms of electricity produced, reduce manual maintenance required and protect the solar cell.*

Due to high land cost in urban areas, the present study is significant for reducing costs when setting up a power plant or even solar panels for domestic use. We have shown an increase of over 100% in the output. The present modeling results are limited to 10-watt, 12-volt polycrystalline solar panels. Our result is more applicable to roof tops of the houses or small-scale plants. However, the justification of the installation costs associated with solar panels must be considered. Thus, one needs to have an optimal cost when designing the number of solar panels required for a certain power requirement. It should also be based on the site location.

1. Problem Statement

Today, the whole world uses electricity, it has become an integral part of our lives. We rely on it for many important services that maintain our way of life. The main sources of power that we utilize are coal and oil, both of which produce pollutants that are harmful to the atmosphere and the environment. By relying on non-renewable energy sources, the price of energy rises exponentially, and eventually becoming too expensive to incorporate into a power plant. Recognizing this urgent issue, we have decided to focus our study on improving the state of solar energy generation as an alternative to non-renewable resources. With improvements in technology and more sophisticated solar panels being designed each year, solar energy is slowly becoming as cost-efficient as coal and oil. However, this new field has many challenges that must be overcome before it can be established as a major source of energy. We want to assist in solving one of solar energy's pressing issues faced while considering switching to solar power generation, the high initial investment cost and large area required for setting up a solar power plant. If the power generated per solar panel is increased this inevitably leads to a decrease in number of solar panels required to reach targeted output of the power plant and hence reducing the total land and solar panel acquisition costs hence greatly reducing the investment required.

Objectives:

1. To use methods to enhance energy generation such as developing a model consisting of solar panels facing each other which make use of sunlight reflected off either of the panels.
2. To develop a feasible solar panel model for both domestic and commercial use.

2. Methodology

After a lot of brainstorming sessions and consulting various research papers, we concluded that the two panels should be placed at 24° tilt towards either side to ensure maximum absorption during both halves of the day (before and after noon) in case of cloudy weather during either time and to avoid either of the panels casting a shadow over the other one as reflected in the model.

A setup with a single 10-watt, 12-volt polycrystalline silicon solar panel was made with complete circuitry and readings of voltage and current at different times were taken to calculate total average output of a single solar panel with same specifications as the solar panel used in project design. A prototype model of the design was fabricated and was set up along a circuit consisting of a DC-AC converter box, energy meter and a LED bulb for providing an output to complete the circuit. The energy meter alongside a digital multimeter were used to determine and record the output of the designed model. Two solar panels identical to the solar panel used in single panel system were used for greater accuracy.

A comparative analysis of the results from both of these systems was done to determine and experimentally validate the effects of the changes in design on efficiency of solar panels.

3. Theory:

Absorption and reflection of incident sunlight

One of the main reasons for the low efficiency provided by solar panels is that when sunlight is incident on a panel, not all of it is absorbed by the panel due to reflections from both, the photovoltaic cells as well as the dust resistant protective glass cover on the panel. First, let us consider the reflections due to the protective glass layer; The amount of sunlight which can pass through the glass layer to be absorbed by the PV layer below is not constant. It varies with the angle at which sunlight is incident on the glass surface.

If sunlight hits the plane in which the glass layer lies perpendicularly, up to 99% of the sunlight can pass through to the PV layer where it is absorbed by semiconducting material to generate electricity. However, if it is incident at an angle of about 10° then more than 90% of the incident sunlight is reflected off the glass and a very small amount makes it through to the PV layer. Secondarily, we must consider the reflections by the PV layer itself. This factor depends upon the type of PV cell technology used in the model as each type of solar cell has a different baseline efficiency.

In the design proposed by us, when the two panels are kept facing each other, a portion the sunlight reflected off one panel is then incident on the opposite panel where it is once again, absorbed and reflected. The exact amount of absorbed and reflected sunlight varies according to the factors mentioned above. This model also makes optimal use of the total amount of sunlight received before sunset. The panel facing east absorbs maximum sunlight from sunrise up to noon (approx.) as sunlight is directly incident on it during this period and the panel facing west makes use of maximum sunlight in the period after that up to sunset as sunlight is directly incident on the second panel during this period.

4. Procedure

As mentioned in the preceding sections, two setups were made for a comparative analysis to judge the benefit of the prototype model. One setup with a single solar panel made according to conventional means and other with two solar panels facing opposite directions according to the results of the study.

A digital multimeter was used to record voltage and current across a resistive load (LED bulb) and open circuit voltage across the same in both cases over a span of 5 days. Two readings were taken daily, the first one being between 9-9.30 AM and second one between 4.30-5 PM IST. All readings were conducted at DY Patil Knowledge City [18.6211719, 73.9107659].

5. The Data

5.1 Formulae and notations:

V = Voltage across resistive load in volts measured using digital multimeter [Constant load used in all cases]

I = Current in amperes across the circuit measured using digital multimeter

P = Power in watts generated by the solar panel model [Calculated value]

$P = V \times I$

Table 1: Readings for project model with two solar panels:

Day	Voltage (Volts)	Current (Ampere)	Power (Watts) [P = V × I]
Day 1	12.6	0.98	12.34
Day 1	12.1	0.95	11.495
Day 2	8.7	0.62	5.39
Day 2	6.3	0.47	2.96
Day 3	10.4	0.82	8.528
Day 3	11.8	0.88	10.384
Day 4	12.2	0.9	10.98
Day 4	11.4	0.9	10.26
Day 5	12.3	0.94	11.56
Day 5	12	0.96	11.8

Table 2: Readings for setup with single solar panel:

Day	Voltage (V)	Current (A)	Power (Watts)
Day 1	8.2	0.36	2.92
Day 1	7.8	0.35	2.73
Day 2	5.7	0.22	1.254
Day 2	4.1	0.17	0.69
Day 3	6.7	0.29	1.943
Day 3	7.7	0.31	2.387
Day 4	7.9	0.33	2.6
Day 4	7.4	0.34	2.52
Day 5	8	0.38	3.04
Day 5	7.8	0.35	2.73

Readings taken with the above setup are for a single solar panel whereas the readings taken with the prototype model used for our experiment are for two solar panels. Hence, for an accurate comparative analysis of both the setups, we must consider twice the amount of power for the single panel setup.

Table 3: Calculations for two solar panels placed according to conventional design:

Day	Single panel power (Watts)	Single panel power × 2 (Watts)
Day 1	2.92	5.84
Day 1	2.73	5.46
Day 2	1.254	2.508
Day 2	0.69	1.38

Day 3	1.943	3.886
Day 3	2.387	4.774
Day 4	2.6	5.2
Day 4	2.52	5.04
Day 5	3.04	6.08
Day 5	2.73	5.46

Table 4: Comparative analysis of both cases to determine increase in power generation obtained by prototype of proposed project design:

Day	Power generated by prototype model - A	Power generated by standard setup - B	Difference – C = A - B	% Increase in power generated = C ÷ B × 100
Day 1	12.34	5.84	6.5	111.3
Day 1	11.495	5.46	6.035	110.5
Day 2	5.39	2.508	2.882	114.91
Day 2	2.96	1.38	1.58	134.05
Day 3	8.528	3.886	4.642	119.45
Day 3	10.384	4.774	5.61	117.51
Day 4	10.98	5.2	5.78	111.15
Day 4	10.26	5.04	5.22	103.57
Day 5	11.56	6.08	5.48	90.13
Day 5	11.8	5.46	6.34	116.11
Average	**9.5697**	**4.5628**	**5.0069**	**109.73**

6. Images of setup:

Image 1: Image of prototype model setup

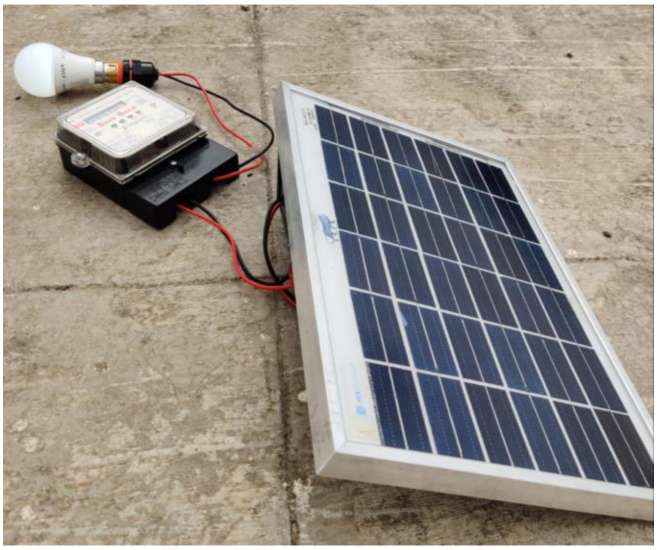

Image 2: Single panel setup with standard orientation used for comparative analysis

7. Concluding remarks and scope for future work

If the model proposed by our study is approved for development and use, then it can provide an alternative with higher efficiency to size ratio.

According to tests performed under natural environmental conditions for both prototype of proposed model and standard setup, the proposed model shows an average increase of 109.73% in power generated according to observations over a span of 5 days.

When integrated with a self-cleaning system proposed design reduces the need for regular maintenance. Automatic cleaning is proven to be most effective for a large solar farm located in semi-arid areas, where frequent cleaning is required due to sand deposition and can maintain efficiency of panels which could otherwise drop by up to 60% [According to data collected by the Thar Desert Solar Power Plant].

A model which provides greater output while occupying the same area as conventional solar panels has great applicability in the public sector, especially so for domestic usage.

In the future, this design can be used to advance research in the portable solar panel sector as well for applications such as charging of an electric vehicle.

According to the significant reduction of solar energy electricity production cost, this source of energy can be used as a major source in the future.

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