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Arduino based Solar Tracking System with Aluminum Foil Reflectors and Cooling System for improvement of Efficiency

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Abstract. Fuel thirst and shrinking nature of conventional fuels has led many countries investigate for eco-friendly sources of energy. Solar radiation based power is one such clean, alternative, abundant and eco-friendly energy resource. Electricity and heat are two useful forms of solar energy. As electricity demand surges every minute, hour and day, the conversion of solar radiation based energy to electrical energy through photovoltaics is also becoming popular, therefore. But, deficiencies still exist which bring down the overall conversion efficiency. This includes overpricing of cells. Reflectors are off late used to improvise the heat focus rate on to the panels. In this case, lack of heat treatment has a direct effect on conversion efficiency. In this paper, we are presenting a scheme called aluminum foil reflected solar panel with tracking and cooling mechanism.

1 Introduction

Current times, climate change across the world is at a delicate level. Natural causes and human interferences have resulted in climate change. Human interference comes as we have released high amounts of green house gases causing global warming [13]. These green house gases are an output of using nearly extinct fuels. Hence there is a need; an immediate one to reduce the usage fossil fuels and move towards renewable sources. At this juncture, solar energy can be viewed having a vast potential [5, 9, 11].

2 Proposed System

In the proposed work of this article, we propose a tracking system for solar panels along with reflected panels to improve efficiency. Solar power generation is proposed to be implemented with maximum power point tracking employed [10]. Here solar panels are proposed to be put in multi-axis rotation implementation for this purpose. Reflecting mirror technology, in our case, aluminium reflectors attachment is in cross parallel to the solar panel in order to increase the intensity of solar radiation inflicting on the solar panels. The reflectors are used to extract radiation to their maximum. The additional heat which is a possible hindrance to the efficiency of the solar panel can be removed/compensated using cooling system attachment to solar panels. The cooling system is of water based cooling [4]. The system proposed we understand increases the panel efficiency along-side working efficiently in partially shaded conditions namely on a cloudy day.

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3 Block Diagram

The block schematic diagram of the proposed work is shown in figure 1. This has the following components namely four number of IR sensors connected to LDRs, Four side reflectors, two DC gear motors [8] with motor driver, a pumping motor, an Arduino based controller setup which hosts the program code for panel control operation and a DC battery back-up to power the entire support system developed around the solar panel [6].

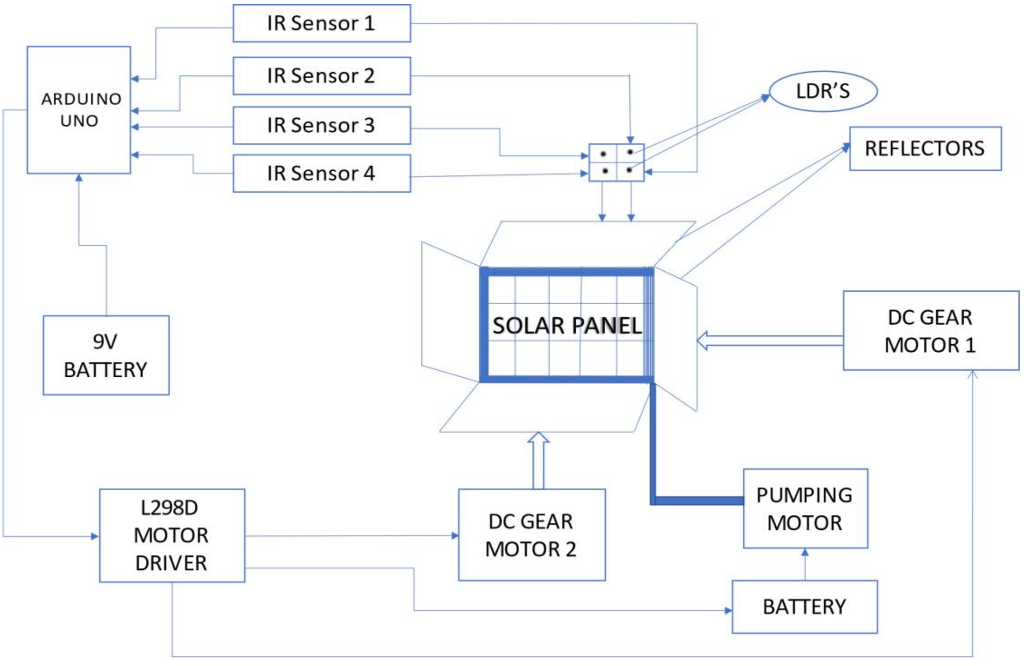

Fig. 1. Block Diagram of the proposed system

4 Component Alignment and Implementation

The block diagram consists of a solar panel, which converts the absorbed sun's radiation into electricity. The LDRs are used here as sensors to detect the intensity of solar radiation accurately. They are used to know whether solar radiation is present or absent at a point of time. It has 4 LDRs which have an indirect connection to the panel in order that they receive same illumination as that of the solar panel for intensity monitoring. The LDRs have variable resistance and that resistance varies along with the light intensity and is connected to IR sensors which receives the signal from the LDRs and sends it to the Arduino. Arduino is at the heart of this entire module [7]. The control program which works with the rotary motors is dumped in Arduino. With the help of dumped code, it operates the entire system. According to the signals, which are received from the LDRs based on the irradiation content, Arduino sends the signals to the motor driver. This motor driver is connected to the motors. This is helpful in rotation of PV panel in accordance to the orientation of the sun during the day for trapping maximum intensity. According to the signals received from the Arduino, this motor driver gives supply to the motors and the respective DC gear motors will help rotate the panel in that direction [2, 3].

The rappers type of construction around the panel is the reflectors. These reflect the sunlight to focus more on to the panel. This is done in order to improve panel conversion efficiency. The proposed idea is in increasing the sunlight intensity that falls onto the panel by reflecting sunlight that normally would have missed panel. Reflectors are positioned at an optimum angle in order to gain the greatest possible level of sunlight that could be focused onto the panel. The reflecting panels that were used are made out of aluminium. The other types of reflector material are stainless steel and mirror reflectors. Reflector tilt angle varies around four angles generally namely 30°, 45°, 60°, and 75°.

As the amount of sun light onto the solar panel increases, thermal heating of the panel as well goes up. For removing the excessive heat from the solar panel, we can adopt either air cooling or water cooling [12]. The blue line around the solar panel in the block diagram of figure 1 is water pipe line, which is for reducing the high temperature on solar panel that is for cooling and to also improve efficiency. Ratings of the Solar Panel that is used in this research experimental set-up are shown in table 1 below.

Table 1. Solar Panel Ratings.

S.No.	Name	Rating
1.	Maximum power (P_{max})	20W
2.	Voltage at maximum power (V_{mp})	19.25V
3.	Current at maximum power (I_{mp})	1.04A
4.	Current - short circuit (I_{sc})	1.11A
5.	Voltage - open circuit (V_{oc})	22.5V

A DC Gear Motor is used for rotation operation. It is an all-in-one motor that's a combination of gearbox and motor. The combination of gear head to motor reduces the speed. It also increases the torque output. L298N is used a motor driver for the DC Gear Motor whose specifications are mentioned in table 2 given below. Reflector Tilt Angle is usually defined as the angle between the horizontal plane and the panel (solar PV in this case) at which, it can be set or adjusted to maximize annual energy collection or in that case seasonal energy collection also. As the experiment was performed in Vijayawada city, the tilt angle at which the aluminium reflectors need to be fixed around the solar panel is determined using the following tilt angle calculation.

Tilt Angle Calculation:

Altitude of Vijayawada City = 16.5067°
Longitude of Vijayawada City = 80.648018 °
Formula for Tilt Angle Calculation
= (0.9*Latitude Angle) - 29
= (0.9*16.5067 °) - 29
= 14.14429 °
From Horizontal Surface Tilt Angle
= 90 ° - 14.14429 °
= 75.855 °

Table 2. DC Gear Motor Driver Specifications.

S. No.	Parameter	Value
1.	Voltage of Operation	5V - 46V
2.	Current at Operation	2A
3.	Voltage (Logical)	5V

4.	Current (Logical)	0 - 36mA
5.	Power (Maximum in Watts)	25W
6.	Driver Chip model	H-Bridge motor driver IC (L298, 2-channel
7.	LED Indicators	5V
8.	Drive motor count	Four motor drive capability or one Stepper Motor drive capability
9.	Dimensions of the Module	44 mm x 44 mm x 28 mm (L x W x H)

The battery specifications are listed in table 3.

Table 3. Specifications of the battery.

Specification	Value
Voltage (nominal)	12 Volts
Factor for Self-discharge	2 % per month
State of Charge (minimum)	30 %
State of Charge (maximum)	90 %
Charging rate (minimum)	10 hours
Charging/Discharging Efficiency	96 %
Lifetime of the battery	10 Years

5 Results and Discussion

The results were taken from sunrise in the early morning to sunset in the evening. Figures 2 to 4 shows the Short Circuit current, open circuit voltage and resultant power from solar panels during stand alone operation.

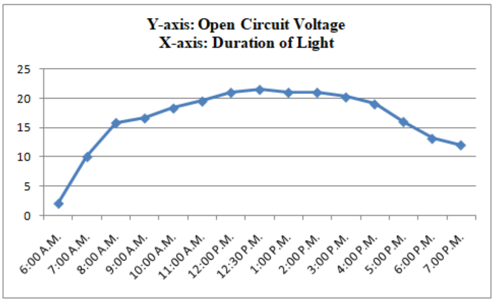

Fig. 2. Open Circuit Voltage (Stand Alone)

The maximum value of voltage is 21.5 volts, maximum current is 0.76 amperes and maximum output power obtained is 16.34 watts.

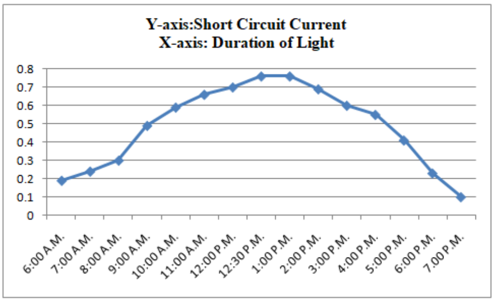

Fig. 3. Short Circuit Current (Stand Alone)

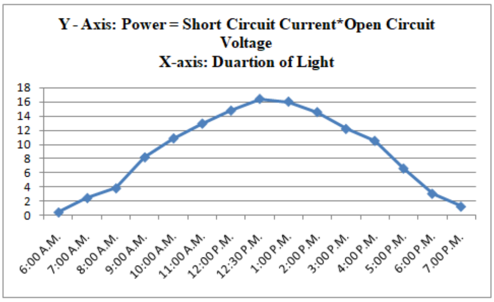

Fig. 4. Output Power (Stand Alone)

Figures 5 to 7 shows the Power outputs with Maximum Power Tracking, Maximum Power Tracking with Reflectors and Maximum Power Tracking with Reflectors provided with cooling mechanism respectively.

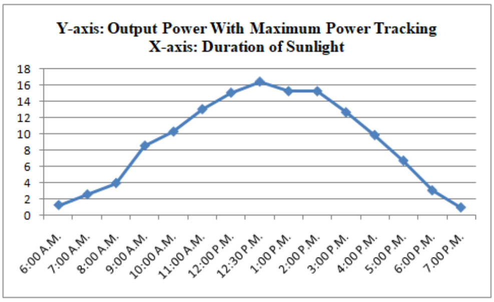

Fig. 5. Power Output (With Maximum Power Tracking)

Figure 5 shows that time vs power, characteristics of solar panel with tracking. The maximum voltage 22.05 volts and maximum current is 0.96 amperes and maximum output power is 16.37 watts.

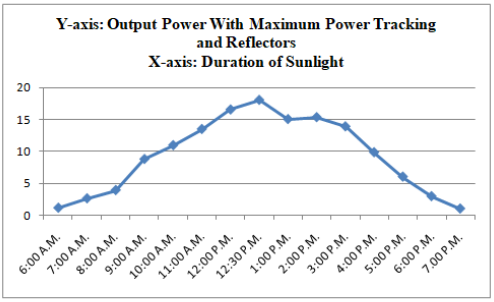

Fig. 6. Power Output (With Maximum Power Tracking and Reflectors)

Figure 6 shows that time vs. power, characteristics of solar panel with solar tracking and reflectors used. The maximum voltage 23.03 volts and maximum current is 0.8 amperes and maximum output power is 18 watts.

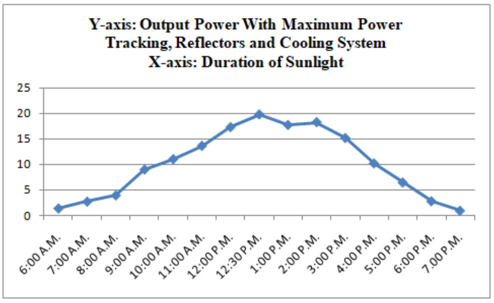

Fig. 7. Power Output (With Maximum Power Tracking, Reflectors and Cooling System)

Figure 7 shows that time vs. power characteristics of solar panel with solar tracking, reflectors and cooling mechanism. The maximum voltage 24.25V and maximum current is 0.81A and maximum output power is 19.7W. Table 4 shows the output powers obtained and a comparison between powers of solar panel without tracking techniques applied and with solar tracking technique that is dual axis tracking applied here along with aluminium reflectors and cooling mechanism for each hour from 6:00 A.M. in the morning till 7:00 PM. until the solar energy dies out in the evening.

Table 4. Comparison of Solar Panel's Output Power under various conditions

Time Frame	Output Power of Solar Panel (Watts)	Output Power of Solar Panel with Solar Tracking (Watts)	Output Power of Solar Panel with Solar Tracking and Reflectors (Watts)	Output Power of Solar Panel with Solar Tracking, Reflectors and Cooling Mechanism (Watts)
6:00 A.M.	0.988	1.2	1.13	1.44
7:00 A.M.	1.957	2.3	2.2	2.76
8:00 A.M.	2.806	2.9	2.6	3.48
9:00 A.M.	5.796	6.325	6.2	7.59
10:00 A.M.	8.477	9.2	10.12	11.04
11:00 A.M.	10.846	11.326	12.45	13.59
12:00 P.M.	12.76	13.16	15.01	17.24

12:30 P.M.	16.34	16.37	18	19.7
1:00 P.M.	14.766	14.72	16.192	17.66
2:00 P.M.	15.015	15.2	16.72	18.2
3:00 P.M.	12.416	12.6	13.86	15.12
4:00 P.M.	3.264	3.5	3.85	10.2
5:00 P.M.	2.624	2.9	2.6	3.48
6:00 P.M.	0.288	0.7	0.09	0.84
7:00 P.M.	0.288	0.699	0.1	1.02

The efficiency calculations are presented next considering the maximum power output obtained in each case.

Efficiency Calculations:
Firstly,
Light intensity = 1000 watts/m^2
Length of the solar panel = 45 cm = 450mm
Width of the solar panel = 35 cm = 350mm
Area of the solar panel = (length) * (width)
= 450 * 350
= 157500 mm^2
= 0.1575 m^2

Secondly, Light input to the solar panel
= (light intensity) * (area of solar panel)
= 1000 * 0.1575
= 157.5 Watts

Based on the above two parameters, the efficiency in four different cases are calculated as follows.

1. **Efficiency of stationary solar panel**

Output of the solar panel = 16.34 Watts
Efficiency = (Output/Input) * 100

= (16.34/157.5) *100

= 10.37 %

2. **Efficiency of the solar panel with Solar Tracking**

Output of the solar panel with solar tracking = 16.37Watts
Efficiency = (Output/Input) * 100

= (16.37/157.5) *100

= 10.39%

3. **Efficiency of the solar panel with tracking and reflection**

Output of the solar panel with solar tracking and reflectors = 18Watts
Efficiency = (Output/Input) * 100

= (18/157.5) *100

= 11.42%

4. **Efficiency of the solar panel with solar tracking, reflectors and cooling mechanism**

Output of the solar panel with tracking = 19.7Watts
Efficiency = (Output/Input) * 100

= (19.7/157.5) *100

= 12.5%

We observe that there is not much difference in the efficiency obtained when a stationary panel is compared to panel equipped with solar trackers. Here, we can observe that the efficiency of the solar based power has increased from 10.37% in case of stationary panel to 11.42% in case of solar panel equipped with solar tracking scheme [1] and aluminium reflectors. We observe this has further improved to 12.5% in case of equipping the system with an additional cooling mechanism. The efficiency comparison graph is shown in figure 8.

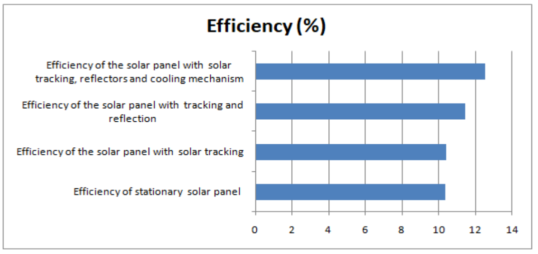

Fig. 8. Efficiency Graph

6 Concluding Remarks

Dual axis solar tracking using an Arduino platform as applied to solar panel with reflector system and cooling mechanism is designed and successfully implemented. We observed this has increased the efficiency of solar panel. The system was observed to be more effective than the existing single axis solar tracker though efficiency wise does not give much improvement.

To harness maximum amount of energy, we have placed reflectors around the solar panel. Though the reflectors are observed to improve efficiency, the efficiency improvement comes with a loss in terms of conversion efficiency lost in terms of heat loss.

To overcome this excessive heat loss, we have placed cooling mechanism for reducing the temperature on the solar panel, so that it helps in increasing the efficiency of the solar panel. This experimental system though a scaled-down version clearly reveals the fact that the system effectively tracks the radiation even on a cloudy day, because of the reflectors and cooling system. Atleast, the efficiency improves by a factor of 20% on a scale of 100%.

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