

Vision based solar tracking system for efficient energy harvesting

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ABSTRACT

Electricity is a major source of energy for fast growing population and the use of non-renewable source is harmful for our environment. This reason belongs to devastating of environment, so it is required to take immediate action to solve these problems which result the solar energy development. Production of a solar energy can be maximizing if we use solar follower. The major part of solar panels is microcontroller with arrangement of LDR sensor is used to follow the sun, where the sensors is less efficient to track the sun because of the low sensitivity of LDR. We are proposing a method to track sun more effectively with the help of both LDR sensors and image processing. This type of mechanism can track sun with the help of image processing software which combines both result of sensors and processed sun image to control the solar panel. The combination of both software and hardware can control thousands of solar panels in solar power plants.

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1. INTRODUCTION

The development of a nation depends on energy but their scarcity continuously increasing. Requirement of enormous amount of energy will need to develop a nation and these required energy can be obtain from the non-renewable sources. Today nearly 85% of energy produced from the fossil fuel but this energy is limited and is major cause of a global warming [1]. That is why we propose this work which offers a sustainable power source to safe grade our world and solve energy crisis & pollution problem. Solar energy is a best renewable source of energy which is environmental pollution free & economical to additional source of energy. Photovoltaic modules are the best way to obtain solar energy and convert it into electric energy. There are different types of material which is used to form a solar panel. If we use Si panel then the panel is 24.5% [2] more efficient than a normal solar panel. Solar tracker is a scheme by which solar panel can track the sun to increase the power efficiency [3], [4]. There are various application of photovoltaic power like robot farming [5], irrigation [6], hybrid energy [7] and smart home system [8] which reduced the dependency upon traditional energy system. Primary aim of my work is to develop a vision sensor, DIP and LDR based solar tracking system using

the programming language C++ consist of simultaneous sensor. Therefore it can improve the effectiveness of a sun panel tracking compare to the fixed system [9].

2. PHOTO-VOLTAIC DEVELOPMENT AND PERFORMANCE

To maximize the output power of solar panel we propose Vision based solar tracking system. Maximum power is achieved at sunshine hour during the tracking of sun and the characteristics of current vs voltage and power vs voltage [10] of photovoltaic cell is indicated in Figure 1.

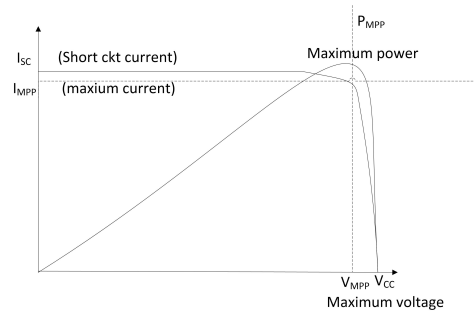


Figure 1. Photo Voltaic response I_{sc} -V and P-V

Researchers have developed many MPPT algorithms to increase the power output of solar panel. Sun follower can improve the performance of the sun tracker by 22% to 56% compared to fixed panel. Sun direction tracing method obtains the azimuth and altitude changes with respect to Sun azimuth and altitude point. Astrophysical equation can also calculate the sun azimuth and altitude [11] point at any time. The Sun azimuth β and the height point Φ [12] can be determined utilizing as shown (1) and (2) respectively.

Where

ρ = latitude angle

μ = Declination angle

η = Solar hour angle

$$\sin \Phi = \sin \rho \sin \mu + \cos \rho \cos \mu \cos \eta \quad (1)$$

$$\sin \beta = \frac{\cos \mu \sin \eta}{\cos \Phi} \quad (2)$$

Declination angle is calculated by (3).

$$\mu = 23.45^\circ \frac{360^\circ(284 + d)}{365} \quad (3)$$

Where d = date and Sun hour angle calculated by (4).

$$\eta = (H + E) \times 15 + \Psi - 300^\circ \quad (4)$$

Where

Ψ = local longitude

H = Beijing time

E = Jet lag Let, Sun current position is $(\beta T, \Phi T)$ at time t. After time period T, β & Φ changes to $(\beta t + T, \Phi t + T)$ and new position given by (5) and (6).

$$\Delta \beta = \beta t + T - \beta t \quad (5)$$

$$\Delta \Phi = \Phi t + T - \Phi t \quad (6)$$

The panel rotates $\Delta \beta$ in the horizontal direction and $\Delta \Phi$ in the vertical direction. In this method, Sun direction can be investigated.

3. PROJECTED SYSTEM

The block diagram of the system is shown in Figure 2, where LDR [13] sensor give their output to microcontroller and camera take Sun image to find Sun center coordinate (AC, BC) by applying image processing [14] algorithm. Finally the refine Azimuth and altitude is calculate given to motor driver which set the Solar panel to focus straight towards the Sun center and cause improve in performance output.

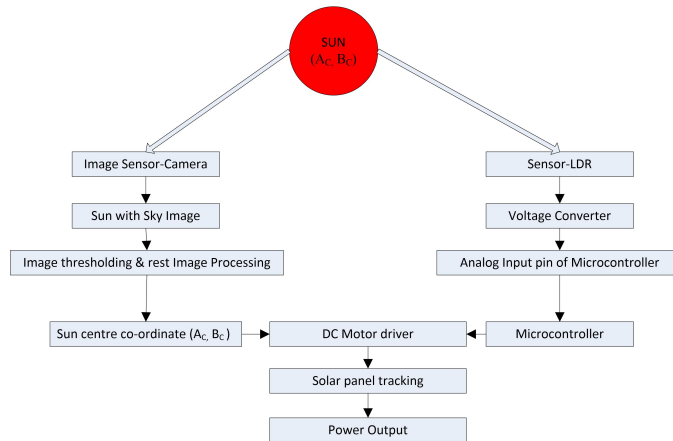


Figure 2. System block diagram

4. DESIGN OF HARDWARE

The system includes 2 servo motor, 4 LDR sensor and Arduino UNO. The LDR sensor [15] sense the intensity of solar light and Arduino UNO control the orientation of panel as Pre-processing [16]. The LDR based tracker circuit diagram shown in Figure 3. The PCB (Printed Circuit Board) design and simulation of project is carried out by Fritzing software shown in Figure 4. The Arduino Uno board, 4 LDR, connecting resistance, Two DC motor and their connection with Arduino board shown in Figure 5.

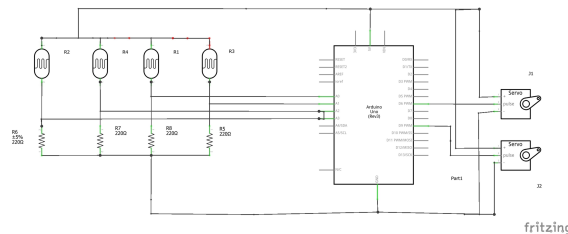


Figure 3. System circuit diagram

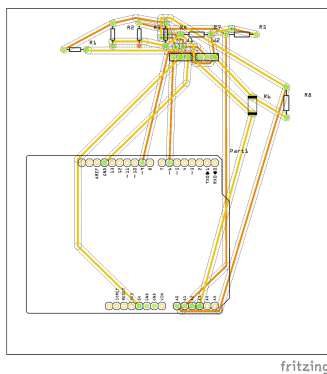


Figure 4. System PCB design

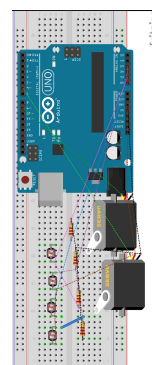


Figure 5. Circuit connection

The above given hardware component list for the system shown in Table 1.

Table 1. Assembly List

Label	Part type	Properties
J1	Basic Servo	12 volt ,10RPM
J2	Basic Servo	12 volt ,10RPM
Part1	Arduino Uno (Rev3)	type Arduino UNO (Rev3)
R1,R2,R3 & R4	Photocell (LDR)	dark 300 kOhms@ 10 seconds; package THT;resistance@ luminance 16 kOhms@ 10 lux
R5,R7 & R8	220Ω Resistor	bands 4; pin spacing 400 mil; package THT; resistance 220Ω; tolerance ±5%
R6	220Ω Resistor	package 2512 [SMD]; resistance 220Ω; tolerance ±5%

5. METHODOLOGY

Proposed system worked on two stages of tracking. The first stage use LDR sensor and second corrected measure taken from Image sensor tracking. Initially the solar tracker performs tracking on Sun intensity by LDR sensor and set panel accordingly. In this tracking there may be error because of partial shadow and out of track condition. This condition is eliminated by second tracking scheme called image tracking. Image tracking use camera near the panel and it takes picture of the Sun with sky is threshold to get Sun image. This sun image [17] is use to find circumference and from this circumference the centroid (AC, BC) of sun is calculated by different image processing algorithm. The calculated centroid will instruct the driver called second track to move the panel direct towards the Sun center. So this two stage tracking improve the tracking accuracy of the sun follower [18].

5.1. Intensity sensor tracking

In this tracking scheme the resistance value of LDR decrease as the sun light intensity increase and its value nearly in mega ohm [19] when sun light is completely vanish. We adjust the LDR's in such a way that if the one side of the LDR focusing Sun then the other side of the LDR remains in dark as shown in Figure 6. The decrease resistance can increase current flow to operate drivers. The sun position change the intensity of light incidence direction on panel because of that the four LDR get different proportion of light cause the vertical and horizontal motion.

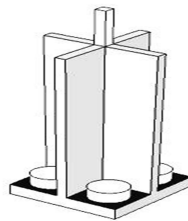


Figure 6. LDR shadow principal

5.2. Image sensor tracking

In this tracking different image processing steps uses to track sun trajectory were discussed in section.

5.2.1. Image processing

The proposed modal calculates the Sun centroid co-ordinate [20] by image processing (IP) technique by using different Sun following steps is given in Figure 7.

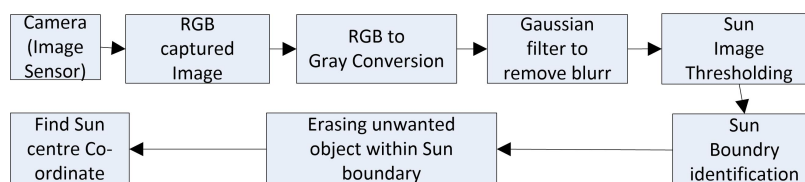


Figure 7. Steps in image processing

5.2.2. Image conversion and noise reduction

The RGB image taken by camera is converted to gray scale image which reduces the complicity of algorithm and take less time in processing. The converted image is contrast starch and the Gaussian filter [21] is used to remove noise from image. RGB and Gray image is shown in Figure 8.

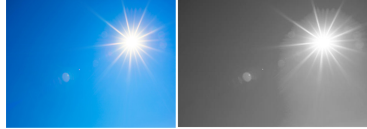


Figure 8. Sun RGB and Gray image

5.2.3. Sun identification

The gray image having some bright spot which represent the cloud. These spots were removed by applying binary thresholding on gray image shown in Figure 9. Some unwanted dot still present in image, were removed by finding largest contours [22].



Figure 9. Binary thresholding of gray image

5.2.4. Estimation of Sun following trajectory

The Sun boundary is segmented [23] and their centroid is calculated from centroid formula. The image center is also calculated and both Image and Sun center [24] were compared to calculate the exact Sun center co-ordinate which instructs the driver [25] to track the Sun.

6. RESULT OF DIFFERENT SCHEME OF SOLAR TRACKER

The proposed model, LDR based and Fixed panel single day reading is taken for 17 hour Sun time were tabulated in Table 2. Comparison of power generation from Fixed, LDR and proposed modal is analyzed in Figure 10 and observed that proposed system generate more power compare to rest two system. Short circuit current graphical representation of all the three system is shown in Figure 11 and evaluated that ISC is same in the entire given modal. VOC of all above said model is calculated and analyzed in Figure 12 and remarked that LDR and IP based system Voc is more compare to Fixed and LDR system. The result state that LDR and IP based tracker produce more power than rest two schemes and their combined parameter analysis is shown in Figure 13.

Table 2. Result of different Scheme of solar tracker

Variable Solar Time	LDR & IP based Solar follower			Fixed Panel			LDR based Solar follower		
	Pout (W)	Isc (A)	Voc (V)	Pout (W)	Isc (A)	Voc (V)	Pout (W)	Isc (A)	Voc (V)
07:00	1.35	0.1	17.3	0.92	0.1	15.7	1.23	0.1	17.1
08:00	2.32	0.1	18.9	1.39	0.1	15.8	1.75	0.1	17.7
09:00	2.73	0.1	19.0	1.91	0.1	16.3	2.53	0.1	18.1
10:00	3.43	0.2	19.9	2.46	0.1	18.0	2.83	0.2	18.4
11:00	4.13	0.2	20.5	2.96	0.2	18.3	3.53	0.2	19.1
12:00	4.96	0.2	20.2	4.57	0.2	19.0	4.89	0.2	20.0
13:00	4.83	0.2	19.7	4.64	0.2	19.2	4.74	0.2	19.4
14:00	4.75	0.2	19.0	3.85	0.2	18.0	4.32	0.2	18.3
15:00	3.81	0.2	18.9	2.75	0.2	16.0	3.26	0.2	17.3
16:00	1.75	0.1	18.7	0.97	0.1	15.3	1.24	0.1	17.0
17:00	1.30	0.1	17.7	0.77	0.1	14.1	1.11	0.1	16.5

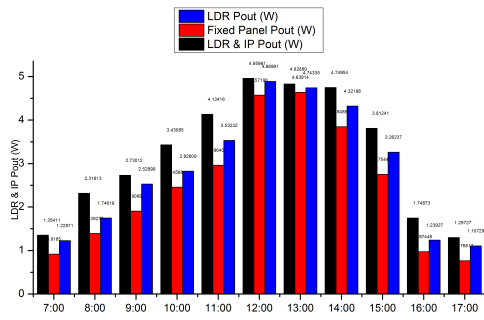


Figure 10. Power comparison of all three systems

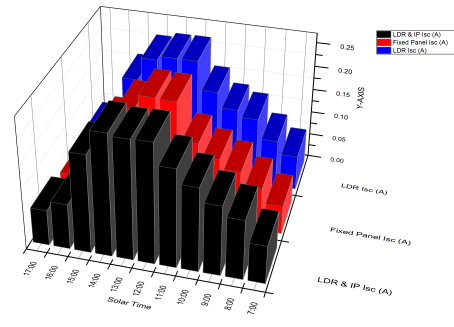


Figure 11. Short circuit current comparison of all three systems

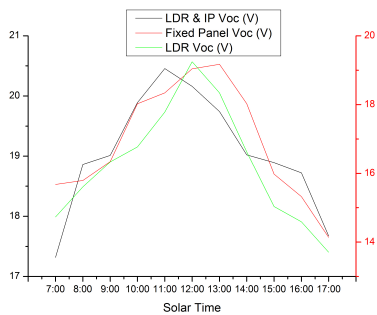


Figure 12. Open circuit voltage comparison of all three systems

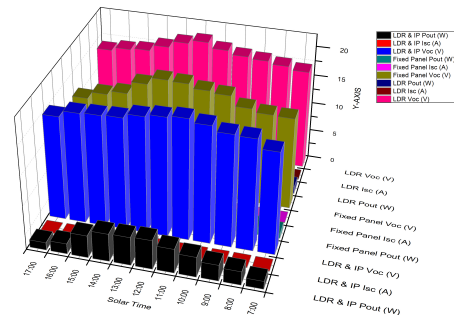


Figure 13. Power, ISC and VOC analysis of all three systems

7. CONCLUSION

Investigating the entire scheme we come to point that LDR and IP based solar tracker produce most fruitful result than other two. Individually LDR is consider best when limited panel have to track, but in condition where hundreds or thousands panel have to track than IP and LDR is best choice because it is cost effective. The efficiency of solar panel will be more if we use the higher resolution camera. Thousands of solar panel trackers of power plant can be controlled by IP and LDR based with the use of PLC. The power generated by solar panel will be used for operating all passive component of system (microcontroller, and servomotor). There are many fields where the vision sensor is prominently used to make system cost effective and free from ambiguous error. Soft computing and vision technique using in robot farming, irrigation system, smart home automation and harvesting of hybrid energy. So in future the Vision technique with soft computing can apply to use in Solar energy farming with least tracking error by maximising panel efficiency.

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