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Research Article

Dual Axis Solar Tracking System using 5-LDR sensor

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Abstract

Limited non renewable energy resources and increasing power demand is a major topic of concern around the world. In recent decades, renewable energy resources are widely used in order to satisfy the increasing power demand and to minimize the damage to the environment. The aim of the paper is to present a unique solar tracking technique which can be used to extract maximum power from the photovoltaic cell by using a close loop control system along with a 5-LDR sensor module which is strategically designed to generate feedback signal in order to track the sun's azimuth and elevation angle. By using the close loop system the tracker will be able to keep the solar panel align to the sun light irrespective to the change in the intensity of light.

Keywords: *Renewable source, Photovoltaic cell, Solar Tracker, Microcontroller, Efficiency*

1. Introduction

Most of the energy consumed by the world is provided by conventional sources such as fossil fuels like diesel, petrol, CNG, coal etc and atomic fuels like uranium, thorium and plutonium, which are limited amount in nature and has worst effect on the atmosphere .Due to increase in population, industrialization and urbanization, the demand of energy is increasing day by day. Key solution to this problem is renewable source of energy. Renewable sources of energy are defined as those sources of energy which are freely available in nature and never exhausting and can be continuously renewed and replenished. It includes solar, wind, geothermal, and hydro and tidal energy. Above all, solar energy is the main source of clean and inexhaustible energy.

A solar cell or a photovoltaic cell similar is to a P-N junction diode. Photovoltaic cell converts the solar energy directly into electrical energy by using the photovoltaic effect [KUO-HUA LIU, (2011)] [Tamer Khatib, Wilfried Elmenreic and Azah Mohamed, (2017)]. Solar cells are the basic building block of a solar panel. Many solar cells are connected in series and parallel to form a solar panel. The potential of solar tracker and PV technology is directly correlated to the incident light available. Output of solar panel depends upon the sun's radiation reaching the PV module. Maximum output is obtained when the light falls at a perpendicular angle on the solar panel. In order to achieve this in real world, the solar panel must be oriented to maintain them perpendicular to the solar radiation throughout the day. This is where the necessity for solar tracker comes. Solar tracking is the most effective approach to enhance the output of the solar panel. Different methods are used to achieve accurate tracking. It is classified as the open loop tracking system and close loop tracking system. In open loop tracking system, mathematical formula is used. Azimuth and elevation angle of the sun were determined by using the algorithm at given date time and geographical information [Soumya Ranjita Nayak and Chinmaya Ranjan Pradhan, (2012)]. Whereas in the close loop system, LDR sensor is used to track the position of the sun which generate the feedback signal in order to continuously track the optimal position.Solar tracking can be done by using single axis tracking method or by using dual axis tracking method [Divya Gnanarathinam.S, Sundaramurthy.S and Amitabh Wahi,(2015)],[Deepthi.S, Ponni.A, Ranjitha.R and R Dhanabal, (2013)]. In single axis tracking system, the solar panel is oriented to track the position of sun in east-west direction.

The solar panels are usually tilted at a fixed angle corresponding to the latitude of the location. Compare to the single axis tracking system, dual axis tracking system track the position of the sun form east-west as well as the elevation angle. With two tracking motor design the panel can be move in all the four direction. Both the motor can work simultaneously by using simple electronic component, 5-LDR sensor and PIC microcontroller [Nader Barsoum,(2011)].

2. Design of Solar Tracking System

Fig.1 elicits the block diagram of a close loop solar tracking system. In tracking operation, the analog error voltage signal received from the sensor is converted in digital signal and processed in controller as per the

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algorithm. Then a command signal is send to the motor driver to rotate the DC motor in the clockwise or counter clockwise direction. The motor will stop when the error signal is less than threshold value.

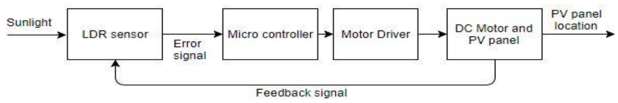

Fig.1 Block diagram of solar tracking control system

Fig.2 shows the algorithm of close loop tracking system in the flowchart form. Each LDR are named as Upper Left (UL), Upper Right (UR), Down Left (DL), Down Right (DR) and the TOL. TOL is the 5^{TH} LDR located on the top edge which plays the role of reference LDR. L, R, D and U are the analog voltage signal produced by the average of UL and DL, UR and DR, DL and DR and UL and UR respectively. As per the design the average analog voltage signal will be low when the corresponding LDRs are shadowed. This will create the voltage difference .If the difference is greater than the threshold value i.e greater than the TOL, and then the motor will operate. In order to obtain maximum power from the solar panel azimuth and elevation tracking is done simultaneously until solar panel is aligned perpendicularly to the sunlight.

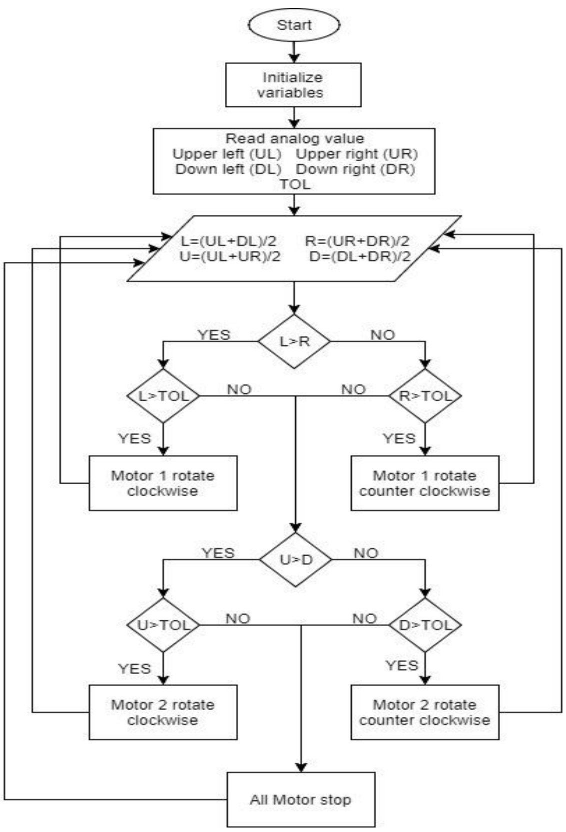

Fig.2 Flowchart for solar tracking algorithm

The main reason behind using the 5^{TH} LDR (TOL) as reference is that, the intensity of light does not remain constant throughout the day. This change in intensity of light will create the variation in the feedback error voltage signal which may not be greater than the threshold value, if threshold value is a constant. Hence, to overcome this problem 5^{TH} LDR voltage signal is used as the threshold value which allows it to change as the intensity of light changes making the sensor to work effectively in sunny as well as in cloudy weather.

3. LDR sensor design

The principle used behind the designing of sensor is Voltage Divider Law. Fig.3 shows the simple series circuit. The applied voltage is divided between two resistors, out of which voltage across one resistor can be used as an output voltage signal. By using equation (1) voltage can be calculated.

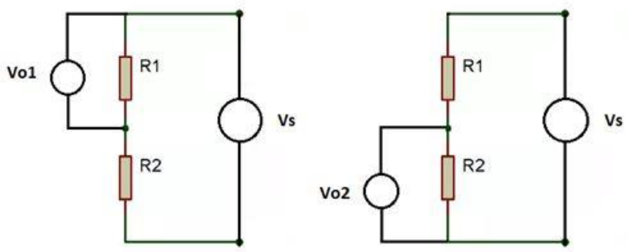

Fig.3 Series circuit

$$Vo1 = \frac{R1}{R1+R2} * Vs \qquad (1)$$

We can conclude form equation (1) that, if R2 <R1 then Vo2 is smaller, if R2 = R1, then Vo1 and Vo2 are half of Vs and if R2 > R1 then Vo2 is greater. The ideology of using LDR in Voltage Divider Law is shown in the Fig.4. LDR is used as transducer, whose resistance value varies according to the intensity of light. This change in voltage is used as an input signal to controller.

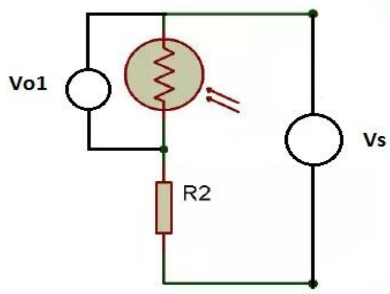

Fig.4 Series circuit using LDR

The value of fix resistor R2 determines the range of output voltage .For better result large range of output voltage is required. This objective is achieved if the resistance of R2 is much larger than the LDR minimum resistance (R_{min}), but much smaller than the LDR maximum resistance (R_{max}). Standard value of fix resistor R2 can be calculated by using equation (2).

$$R2 = \sqrt{Rmin * Rmax} \qquad (2)$$

Fig.5 and Fig.6 shows the design of solar tracking sensor,comprising of 5 LDR and a cross shape design fixed on a plastic plate. Upper Left (UL), Upper Right (UR), Down Left (DL), Down Right (DR) and the TOL are used to detect the azimuth and elevation motion of photovoltaic panel. If the panel is not perpendicular to the sunlight, the shadow will fall on one or two LDRs and will create difference in the light intensity.

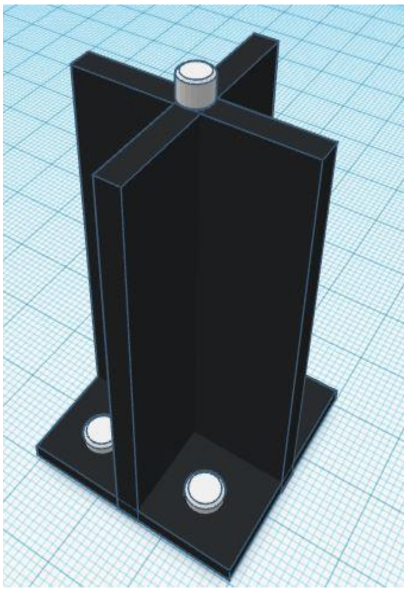

Fig.5 3D design of 5-LDR sensor module

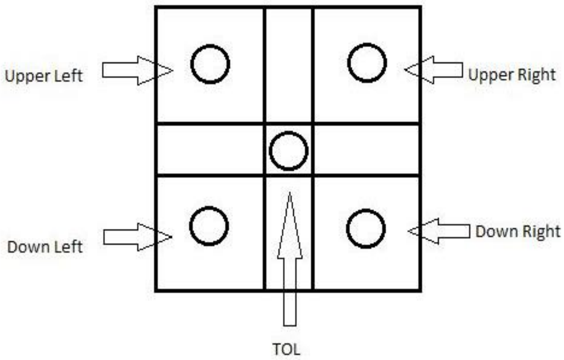

Fig.6 Positioning of LDR

4. Experimental results

Table 1 Current and Voltage value of fixed PV system at different time interval of the day

Time(HR)	Voltage(V)	Current(A)	Power(W)
07:00AM	13.1	0.37	4.847
08:00AM	13.8	0.41	5.658
09:00AM	14	0.45	6.3
10:00AM	14.7	0.44	6.468
11:00AM	15.1	0.48	7.248
12:00PM	15.13	0.5	7.565
01:00PM	15	0.49	7.35
02:00PM	14.95	0.44	6.578
03:00PM	14.93	0.41	6.1213
04:00PM	14.91	0.4	5.964
05:00PM	14.9	0.38	5.662
06:00PM	13.5	0.37	4.995

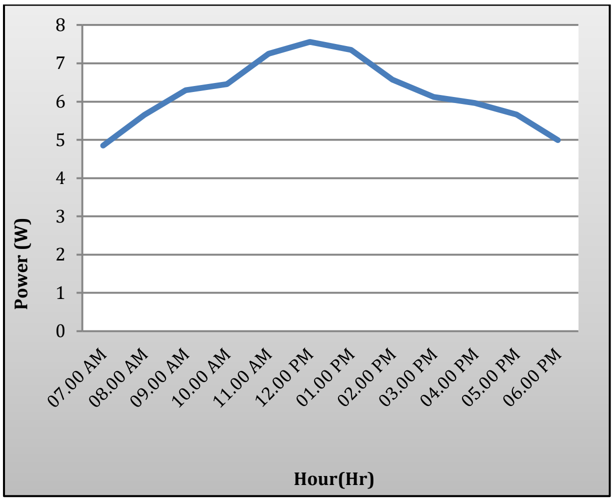

Fig.7 Graph of output power of fixed PV system

Table 2 Current and Voltage value of tracking PV system at different time interval of the day

Time(HR)	Voltage(V)	Current(A)	Power(W)
07:00AM	15	0.41	6.15
08:00AM	16	0.45	7.2
09:00AM	16	0.5	8
10:00AM	15.8	0.53	8.374
11:00AM	15.7	0.56	8.792
12:00PM	15.7	0.57	8.949
01:00PM	15.6	0.57	8.892
02:00PM	15.6	0.56	8.736
03:00PM	15.5	0.54	8.37
04:00PM	15.35	0.53	8.1355
05:00PM	15.32	0.47	7.2004
06:00PM	15.31	0.39	5.9709

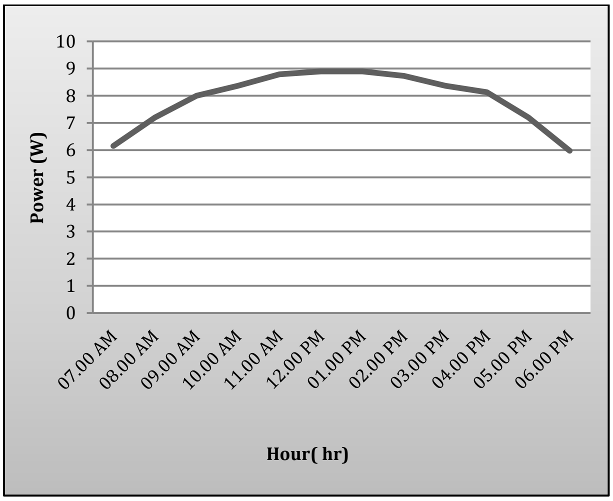

Fig.8 Graph of output power of tracking PV system

Table 3 Power gain of Fixed and Tracking PV system

Time(Hr)	Fixed System	Tracking System	Power gain in %
07:00AM	4.847	6.15	26.88
08:00AM	5.65	7.2	27.43
09:00AM	6.3	8	26.98
10:00AM	6.46	8.37	29.56
11:00AM	7.248	8.79	21.27

12:00PM	7.56	8.9	17.72
01:00PM	7.35	8.89	20.95
02:00PM	6.57	8.73	32.87
03:00PM	6.12	8.37	36.76
04:00PM	5.96	8.13	36.40
05:00PM	5.66	7.2	27.20
06:00PM	4.99	5.97	19.63

Fig.9 Photo of experimental prototype

The experimental results of the fixed and tracking PV system is shown in the Table.1 and Table.2 and graphical representation can also be seen in the Fig.7 and Fig.8. Analyzing the given data, it can be seen that the tracking was less in the afternoon and significantly more in the morning and evening. Power gain by the dual axis tracking system over fixed system is shown in the Table.3. Maximum power output of fixed system is 7.56W and tracking system is 8.9W and maximum power gain is achieved in the morning and evening. Fig.9 shows the experimental prototype of the dual axis solar tracking system. 10W, 12 V rating of Solar panel, PIC microcontroller (PIC16F873A), two motor driving IC (IC L298) and two 3.5 rpm PMDC motor were used.

Conclusions

In this proposed system, the solar tracking system was implemented by using 5-LDR sensor module. Analyzing the given information it can be said that by using tracking system method, maximum power can be extracted from the solar panel. The tracker follows the sun's path throughout the day and keeps the panel orthogonal to the sunlight. In the night it holds is position and next morning it come backs to its initial position as the error voltage signal become greater than the threshold value. The system is cost effective and robust.

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