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Design and fabrication of an automatic dual axis solar tracker by using LDR sensors

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Abstract

Due to the rotation of the earth in an orbit, direction of the Sun changes relatively. This paper represents a setup, which is fabricated to minimize the angle of incidence between incoming light from Sun and a flat photovoltaic (PV) panel to increase the intensity of the light received. It increases the power generated by an installed power generating unit. This setup consists of a mechanical mechanism to tilt the flat PV panel towards the Sun. This mechanism is derived by DC motors having a high reduction ratio. Voltage supplies to these motors are controlled by the LDR (Light Dependent Registers) sensors by the means of electronic circuits. The energy consumed by the tracking system is very less. The cost of the mechanical parts and electronic components are very less. The Microprocessor is not used in this setup. Hence it does not require programming and computer interface. Not any geological data are required, because LDRs work on the differential of the light intensity at the both ends of the plate. The motive of the work is to fabricate a solar tracker at a very low cost.

Keywords: Solar Tracker, LDR, Photovoltaic (PV) cell, Dual Axis, Solar Collectors, Solar power plant

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1. Introduction

Energy is required for the different applications in our daily life. There are so many resources of power generation. 85% of power is produced from fossil fuels (Anuraj & Gandhi, 2014). Due to the depletion of the fossil fuel, renewable energy resources are required. Wind energy, geothermal energy, tidal energy and solar energy resources are some of the most efficient renewable energy resources. Solar energy can be converted in to two forms of energy, i.e. thermal energy and electrical energy. These can be achieved by using some instruments. Solar energy can be converted into electrical energy by using PV (photovoltaic) cells. Rays from the Sun light falls on the PV panel, which generates DC power. This DC power has a direct correlation with the intensity of the light incident on panel. And the intensity depends on the angle of incidence between incoming light and a flat photovoltaic (PV) panel. Figure 1 shows the angle of incidence (θ) and eq.(1) shows the relation between power (P) and angle of incidence (θ).

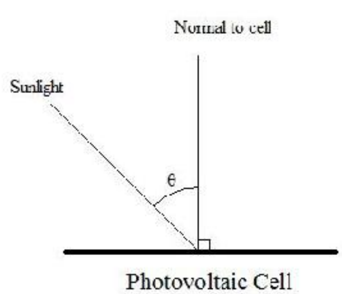

Figure 1. Angle of incidence

The normal to the panel is perpendicular to the panel. The Sunlight strikes the panel at an angle θ. Let the Sunlight is staying at a constant intensity (λ), the available Sunlight to the solar cell for power generation (P) can be calculated as:

$$P = A \lambda \cos\theta \qquad (1)$$

Here, 'A' is limiting conversion factor in the design of the panel because it cannot convert 100% of the Sunlight. Hence, according to Eq. (1), maximum power generated will be when θ=0 means the Sunlight is hitting the PV cell along its normal and no power will be generated when the Sunlight is perpendicular to the normal. If the solar panel is fixed, there is significant power loss during the day. It is due to the rotation of the earth in an orbit, hence the direction of the Sun changes relatively. There would be a variable value of θ. Non zero value of θ causes the loss of power.

A tracking system can keep the angle of incidence equal to 0. Sun tracking systems can increase the power output of solar power plants by 25% to 40%, depending on the geographic location. A single axis tracker can increase power output by 26%, while a dual axis tracker increases power by 32% (Deb & Roy, 2012). Single axis trackers follow the Sun from east to west, while dual axis trackers track the Sun by altitude (up/down), since the Sun moves across the sky throughout the day. Mousazadeh et al. (2009) calculated that the amount of power gained by tracking can come close to an ideal 57% (Mousazadeh et al., 2009).

Tracking systems compose of mechanical mechanism and electronic sensors. Mechanical mechanism rotates the flat panel and this rotation is controlled by electronic sensors.

The controlling process can be classified into three processes, namely passive control unit, microprocessor control unit (Arsalan, 2013) and electro-optical control unit. The passive control unit is a system conducted without any electronic device. The microprocessor control unit needs geological data and programming. The electro optical control unit uses solar detecting devices which are sensitive to solar radiance photo sensors (LDR). Third controlling process is used in this work.

2. Principle of the Work

LDR sensors are mounted at the middle of the side edges of the PV panel as shown in Figure 2. If there is any intensity difference in between LDR3 & LDR4 or LDR1 & LDR2 then a signal produces. This signal reaches to the control system (circuit1/circuit2) and is evaluated there. Then required instruction signal reaches to the motor (motor2/motor1) which is attached to mechanism and the motor rotates the PV panel. LDR1 and LDR2 send the signals to circuit1 and LDR3 and LDR4 send the signals to circuit2. Circuit1 and circuit2 send the signals to motor2 and motor1 respectively, and also operate them. The panel rotates according to this control signal and the movement of the PV panel stops at the position where it directly faces the Sun as shown in Figure 2.

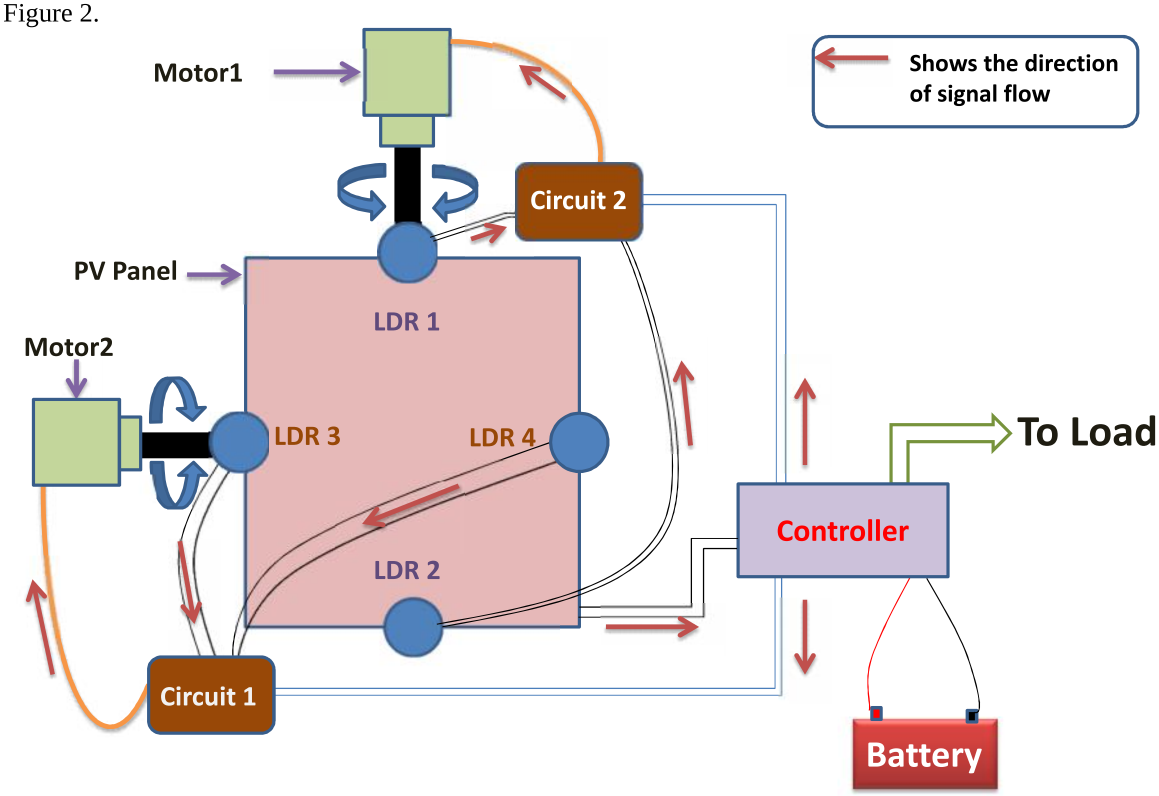

Figure 2: Block diagram of the setup

There is a controller which controls the power storage. DC power generated by the PV panel goes to the controller. The battery is connected with it. It charges the battery. It manages the load also. Power is supplied to the circuits from this controller itself.

3. Constructional Detail of the Setup

Setup has two parts (i) Electronic sensors (ii) Mechanical mechanism. Mechanical mechanism is controlled by LDR based sensors. A Detailed description is given below

3.1 Electronic Sensor's Circuit: In this setup two similar circuits have been used. Each circuit has two LDR sensors as shown in Figure 3. Circuit1 and circuit2 are similar to each other.

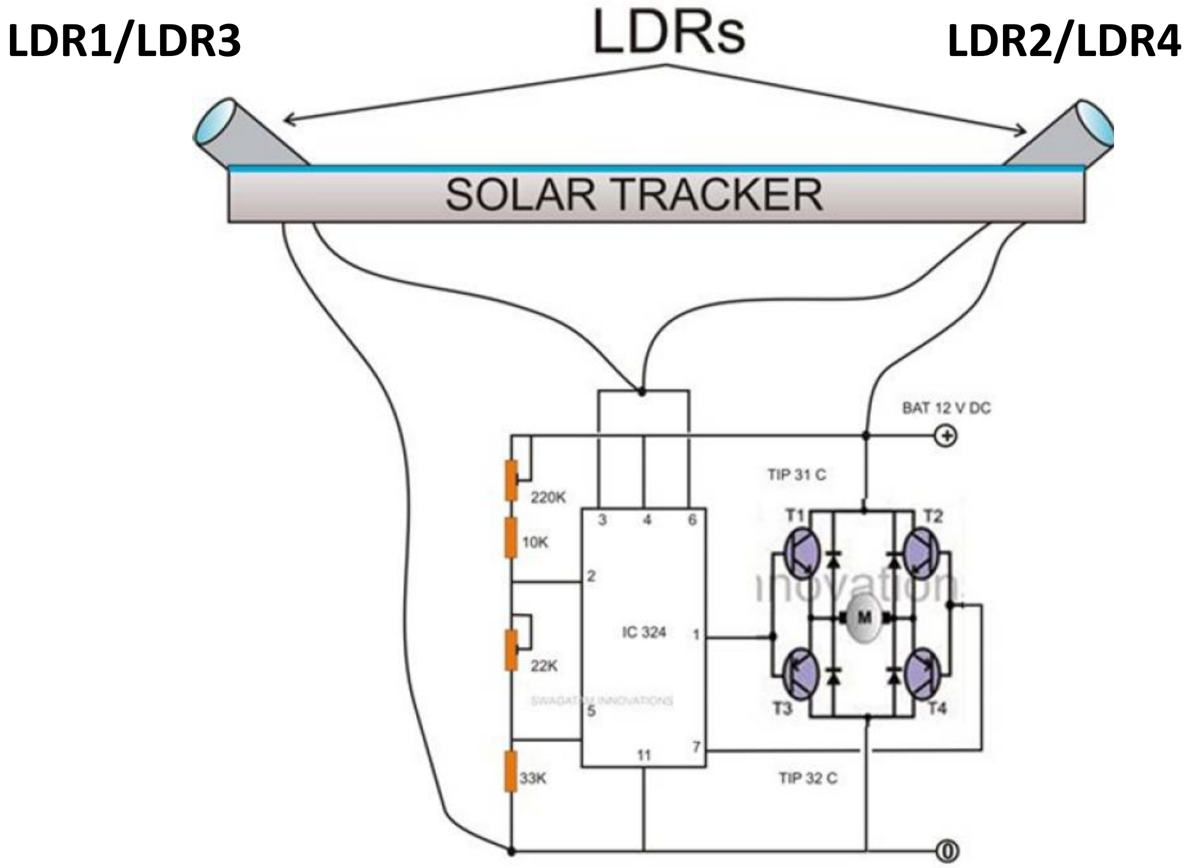

Figure 3. Schematic diagram for circuit1 and circuit2 (Stonecypher, 2011)

A single circuit has many semiconductor components which are 2 LDR sensors (10K at full illumination, infinite at complete darkness), 4 transistors (TIP 31 C, TIP 32 C), 4 Diodes (1N4007), 2 registers (10K, 33K), 2 presets (P1=220K, P2=22K), 1 IC (IC 324), 1 DC Motor. The circuit is fabricated as shown in Figure 3. IC 324 did not require any programming. DC motors are simple purpose DC motors not any stepper motor (Banerjee, 2015).

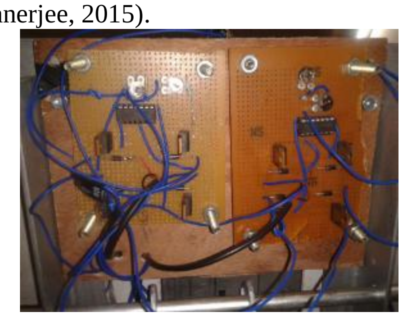

Figure 4. Fabricated circuits, circuit1 & circuit2

The circuit is fabricated by fixing the components over a general purpose PCB and interconnecting their leads by soldering as per the circuit diagram shown in Figure 3. The entire circuit is then housed inside an enclosure, allowing the appropriate wires for the LDRs and the motors to come out of it. Fabricated circuits (circuit1, circuit2) are shown in Figure 4.

3.2 Mechanical Mechanism: Setup is fabricated to rotate the panel about two axes, horizontal and vertical axes. Chain sprocket arrangement is used for rotation about a vertical axis and the lead screw arrangement is used for rotation about a horizontal axis.

The whole assembly is the combination of assembly1 and assembly2. Assembly1 is used for horizontal rotation of the panel. Assembly2 works for rotation about a vertical axis. These assemblies are made up of aluminum material because aluminum is light in weight and high in strength. Fixed frame is made up of mild steel for the foundation's purpose.

In assembly1, PV panel is palced on an ‘I’ shaped frame. This frame is supported at two hinged points, one of them is connected with ‘L’ frame with a revolute joint and another is coupled with an arm. This arm connects the ‘I’ frame with lead screw through a nut. The nut is engaged with a lead screw. The lead screw is connected with DC motor2 as shown in Figure 5(a).

In assembly2, a large sprocket (sprocket1) is fixed and supported another large sprocket (sprocket2) with four ball bearing in between them. These ball bearings are connected with the central shaft through 4 needle shafts so that they could move in a path of a circle with the rotation of upper sprocket (sprocket2). Sprocket2 is connected with a small sprocket (sprocket3) with a chain drive. Sprocket is connected with motor1 through a small shaft as shown in Figure 5(b). Assembly1 is mounted on the sprocket2 of assembly2 as shown in Figure 5(b). This whole setup is founded on a fix frame. Assembly2 is covered with hardboard for the attractive look. But some components can be seen in Figure 5(b).

Figure 5(a). Assembly1 of the setup

Figure 5(b). Assembly2 of the setup

3.3 Finalization of Setup: In the previous paragraphs, description of electronic circuits and mechanical mechanism was given. From those we have a physical setup. Once the whole setup is fabricated, mount the LDR sensors on the panel at the opposite ends of the panel which was discussed in section 2. These sensors are surrounded at the periphery with black tape. Fix the circuits at the back of the panel. Make all the wire connections by providing an ON/OFF switch at the power sources of the circuits.

Figure 5(c). Complete assembly of the setup.

4. Calibration of the setup

After the completion of the whole setup, it needs calibration. Circuits were calibrated one by one. Calibration was done in a dark room. Calibration was very easy and was done with the following steps:

1) Circuit1 was calibrated first.
2) Switched off the power supplies of both the circuits i.e. circuit1 and circuit2.
3) Set the presets P1 and P2 at the extreme positions with the help of a screw driver.
4) Switched off all the lights of the room. A very small light source was there to see presets (P1 & P2).
5) Switched on the power supply of circuit1 only.
6) By supplying the power to the circuit, motor2 rotated in any of the direction (clockwise or counter clockwise).
7) Tuned the presets P1 and P2 such that motor stopped. Tuning was done in the following steps:
    i) At the start, kept the preset P1 at extreme position, rotate the preset P2 very slowly up to the other extreme position with the help of a screw driver.
    ii) Then rotated P1 very slightly and rotated the preset P2 very slowly up to the other extreme position with the help of a screw driver.
    iii) Repeated the step (i) and (ii) until the motor stopped.
    iv) Switched off the power supply of circuit1.
8) After calibrating circuit1, calibrated circuit 2. Switched on the power supply of circuit2.
9) Repeated the steps 3-4 and 6-7. And switched ON the power supply of circuit1 also.
10) Checked weather both the motors were at rest or not. Both were at rest, calibration done.
11) Switched OFF both the power supplies and switched ON the lights of the room.

5. Testing/Working of the setup

Switch ON the power supplies of both the circuits. A light lamp can be considered as a Sun.
Three conditions are shown in figure 6.

(A) When intensities are same

The most stable position is when the two LDRs having the same light intensity. Panel faces the Sun. Setup rests in a steady position.

(B) *East light Intensity is greater than the west light intensity*

When the light source moves in the left direction, i.e. the Sun moves from west to east, the level of intensity falling on both the LDRs changes and this change is read by the controller and motor rotates the solar panel in a way so as to track the light source as shown in figure 6.

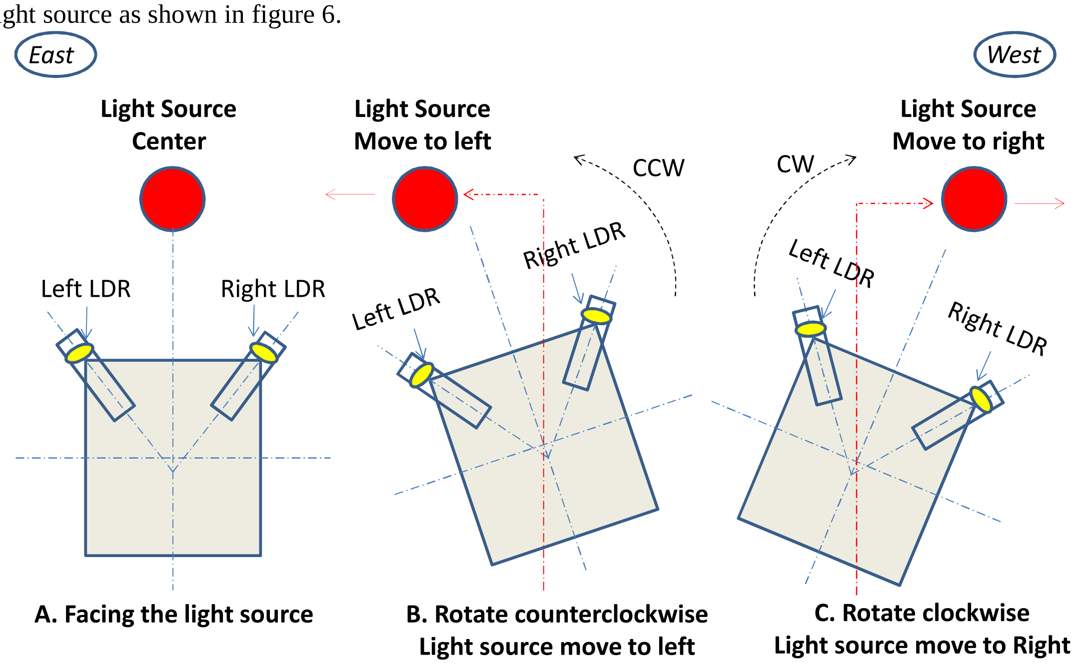

Figure 6. Representation of follow up by the Sun.

(A) *West light Intensity is greater than east light intensity*
When the light source moves in the right direction, i.e. the Sun moves from east to west, the level of intensity falling on both the LDRs changes and this change is read by the controller and motor is used to rotate the solar panel in a way so as to track the light source as shown in figure 6.

It happens in the perpendicular direction also.

6. Results

The result of this work is a physical observation only. Panel traces the Sun like a Sun Flower. In the morning, panel is placed by facing the sun. As the sun changes its position, along this, panel also tilts to face the sun. This process will continue till the evening. Hence we can say that by using this setup, the panel can rotate in the required direction, following the path of Sun to get maximum energy. With the help of this setup, the efficiency of the solar panel would increase. Power generated by the plant increases.

7. Features of the Designed Tracker

The efficiency of the solar panel can be increased very efficiently and economically. The components used in this setup are very cheap and can be availed from the market very easily. Cycle sprockets are used at the place of worm and worm wheel which decreases the cost(Bhupendra Gupta, Neha Sonkar, Brahman Singh Bhalavi, 2013). And these sprockets can be from the scrap materials. IC used in the circuit is cheaper than the microcontroller. It doesn’t require any programming. It decreases the cost of setup. One another factor is also there with this setup which decreases the cost i.e. motor. These motors are simple DC motors, not any stepper motor. Energy consumed in the solar tracker is negligible.

The main application of this setup is in electric power plant units. But it can also be used for heating water solar collectors also.

8. Conclusions and Future Scope

The use of this technique can capture large amount of solar energy. By using this setup, the use of the non-conventional energy will increase, which is very fruitful incident of our future power sector. It is the main contribution that once the simplicity of solar energy system design is understood, engineers and manufactures will provide new system designs that will expand the solar market worldwide. Dust particles present in the atmosphere in a large quantity. They cover the panel. This becomes an interruption in the direct contact between Sun light and PV cells. It may decrease the efficiency of the solar power plant. Hence an automatic system can be designed and fabricated for the cleaning of the panel. It may be like a wiper of the car.

Nomenclature

LDR	Light Dependent Register
PV	Photo Voltaic

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Biographical notes

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