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# Dual Axis Solar Tracking System with Realtime Monitoring System

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**ABSTRACT**

The dual threats of energy depletion and global warming place the development of methods for harnessing renewable energy resources at the center of public interest. Solar energy is one of the most promising renewable energy resources. Sun trackers can substantially improve the electricity production of a photovoltaic (PV) system. This paper proposes a novel design of a dual-axis solar tracking PV system which utilizes the feedback control theory along with a four-quadrant light dependent resistor (LDR) sensor and simple electronic circuits to provide robust system performance. The proposed system uses a unique dual-axis AC motor and a stand-alone PV inverter to accomplish solar tracking. The control implementation is a technical innovation that is a simple and effective design. In addition, a scaled-down laboratory prototype is constructed to verify the feasibility of the scheme. The effectiveness of the Sun tracker is confirmed experimentally. To conclude, the results of this study may serve as valuable references for future solar energy applications.

**KEYWORDS:** dual-axis Sun tracker, photovoltaic panel, feedback control theory, light dependent resistor, stand-alone PV inverter, energy gain.

## 1. INTRODUCTION

Solar energy systems, or PV systems, from compact and simple as in pocket calculators to complicated and powerful as in space station power supplies, are all made possible thanks to the phenomenon called photovoltaic effect, the conversion from solar energy to direct current electricity in certain types of semiconductors. The full understanding of the process requires understandings of different physics concepts, such as photons and solar radiation, semiconductor structure, conversion between solar radiation, chemical energy and electrical energy. Within the scope of this project, which is developing a tracking module, the principle of the phenomenon has only been covered and explained to some extent. This part of the paper will be focusing on practical and engineering aspects of the topic, such as the structure of a PV system, its subsystems and components, mechanical setup, and other factors that influence PV systems' performance and efficiency. Especially, the structure of a solar tracking system will be covered, with some physics knowledge behind its operation. Internationally, Morocco is considered to be the world leader in terms of solar energy production. 20% need of the country has been met by solar energy in Morocco. Morocco is the world's biggest country to have concentrated solar power. Concentrated solar power focuses all solar rays at one point and tries to produce a thermal energy from it, then this thermal energy is converted into electrical energy. On the other hand, normal solar panels use

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Photovoltaic cells to convert solar energy to electric energy. The power received by the earth through the sun is about 1.8*1011 MW, This is enough solar energy falling on earth to met need of electricity. Solar energy on Earth is 10000 times more than the global electricity requirement. It is been estimated that solar energy received from sun only for 1.5 hours can meet the annual global energy consumption. So energy crisis can easily be solved by solar energy. In Spite of this many countries are not actively participating in this revolution. Solar energy acquires a large amount of area due to which there is wastage of land. To tackle this problem we need to increase efficiency of solar projects. In order to gain maximum power output from PV panels, one needs to keep the panel in the most appropriate position. So that sun radiations are orthogonal to the panel during the day (ss). Hence it is essential to trace the sun position and align solar panel perpendicular to sun. This tracing can either be done in single axis or in dual axis.

**Literature Survey**

New low-cost single axis passive solar tracker based on a shape memory alloy actuator is developed. Main advantages of this tracker are relatively low price (below 150 US $/m2), collectible energy surplus up to 40% (compared to fixed tilt collectors), extremely simple, modular solid state design, automatic morning orientation, tracking angle 140° and sealed case [7]. The most efficient and popular sun-tracking device was found to be in the form of polar-axis and elevation types [8]. Improved solar cells have been developed and the use of solar tracking system over the use of traditional fixed PV system is growing. This paper gives a comprehensive review on solar tracking systems and their potentials in solar energy applications. The paper overviews the design parameters, construction, types and drive system techniques covering different usage application [9].

**System Architecture**

The project called "Automatic Solar Tracking System" is produced through installation of the various nitty-gritty such as solar panel which provides 12 volts as output, an Arduino as MCU, a motor driver – with IC L293D, two LDR sensor module, a 10 r.p.m. simple DC motor, a current sensor and a 9 V battery. Construction of the said project is being built out of the wooden base installed at the ground of it, affixed with the iron rods on both the sides in a cross-shaped manner connected with a hollow cylindrical rod from both the sides and the DC motor is clinging at one edge of the hollow rod. Three-fold sections into which the circuit of the solar tracking system is divided.

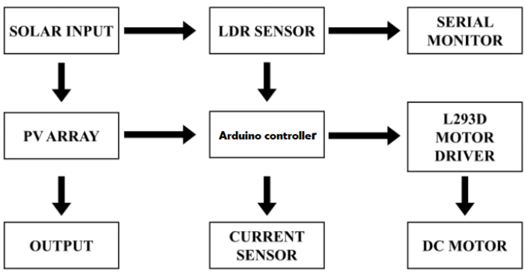


Figure: Block Diagram

The input stage has two LDR module that is so arranged to form a voltage divider circuit, the microcontroller is programmed through the software named Arduino ide being decked up in the system and lastly the driving circuit that has the DC motor helps in rotating the solar

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panel. The motor driver is embraced with three terminals- two for motor input/ output respectively and the third one for power input. The terminal for motor input is connected to 2 of the 14digital input/output pins of Arduino UNO and subsequently, the motor output terminal is connected to the DC motor. The two LDR sensor modules are annexed to the scaffolding with Arduino analogue inputs. The light dependent resistors are then affixed along the length, on either side of the solar panel.

Before being consolidated into one system, three independent stages are engineered independently. This approach, similar to stepwise refinement in modular programming, has been employed as it ensures an accurate and logical approach which is straight forward and easy to understand. This also ensures that if there are any errors, they are independently considered and corrected.

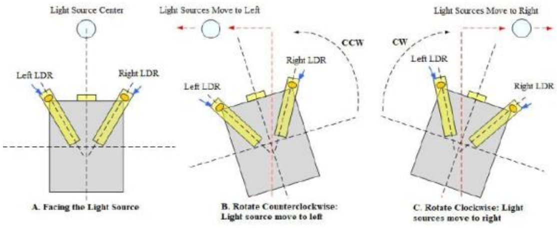


Figure: Concept of using Two LDR

The figure depicts the notion for the installment of the light dependent resistors (LDR). A secure state is attained when the light intensities of the two LDR become the same. The principal source of light energy, the Sun, moves from east to west. This movement of the Sun causes the variation in the level of light intensities falling on the two LDRs. The designed algorithm compares the variation in the light intensities inside the microcontroller and the motor then is operated to rotate the solar panel, so it moves aligned with the trail of the light source.

### a) Research Design

Contemplating the idea of building the said project, the idea that has been conceived primarily is to make the best use of solar energy. The next path that unravels is firstly the method to be adopted in storing the solar energy at its maximum level which further ends up with hatching of the project called "AUTOMATIC SOLAR TRACKING SYSTEM''. Culminating towards making the said project caviar in its utilization several components have been unleashed, some of which are mentioned so

1. Solar Panel
2. DC Motor
3. L293D Motor driver module
4. Arduino Controller
5. LDR sensor module

All in consolidation of the said components the concerned project is orchestrated, ought to seek for imbibing the sun rays at its maximum level through the LDR sensor module etched on the edges of the solar panel in accordance with the length of it, revolves in aid with the DC motor by maintaining the proportionality of the Sun's movement. Therefore, the genesis lies

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upon the fact of making solar energy a profitable source in the production of various other aspects which are in rest with the acute need of the society. In addition to which it would be further worthier to state that when the world is being maligned and sick through the pollution ruckus this project could unveil to be a robust endeavor

The emission of solar radiation is somewhat constant and the intensity this radiation hitting a unit area of the earth's crust is also constant, known as solar constant. The value of this solar constant can be expressed as:

$$G_{SC} = \sigma . T^4 . \left(\frac{4\pi R}{4\pi D}\right)^2 = 1367\ W/m^2$$

The absorption of solar radiation on the surface of the earth also varies with different parameters. Latitude and longitude are one of the prescribed parameters. The sunlight is observed at different angles depending on the place on the earth and the angles of the sun. The sun's angle can be classified into the following:

**The elevation angle** is the angle made by the sun with the horizon. The elevation angle is 0 degree at sunrise and 90 degrees around noontime, at the equator. The elevation angle is different at a different time of the day and different for different latitudes. The depicted formula can be used to determine the elevation angle.

$$\alpha = 90 + \varphi - \delta$$

**Zenith angle** is akin with elevation angle. The only difference being it is measured along the vertical. Therefore, it's the angle between the sun and the vertical i.e. Zenith Angle = 90° – elevation angle.

$$\zeta = 90° - \alpha$$

**Azimuthal Angle**, this is the compass direction from which the sunlight is coming. At solar noon, the sun is directly south in the northern hemisphere and directly north in the southern hemisphere. The azimuth angle varies throughout the day. At the equinoxes, the sun rises directly east and sets directly west regardless of the latitude. Therefore, the azimuth angles are 90 degrees at sunrise and 270 degrees at sunset.

Sunrise and Sunset time can be formulated by the following formulas

$$\text{Sunrise} = 12 - \frac{1}{15°}\cos^{-1}(-\tan\varphi\tan\delta) - \frac{TC}{60}$$

$$\text{Sunset} = 12 + \frac{1}{15°}\cos^{-1}(-\tan\varphi\tan\delta) - \frac{TC}{60}$$

Where φ being the latitude of the place, δ being the declination angle and TC is the Time Correction.

**Algorithm Used In Arduino**

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Step1: Start.
Step2: Define the initial position value to Servo Motors.
Step3: Assign analog LDR outputs & PWM servomotor inputs to the arduino.
Step4: Collecting analog values of each LDR i.e., topl, topr, botl, botr.
Step5: Now calculating the average i.e., avgtop (Average of top left and top right), avgbot (Average of bottomleft and bottom right), avg left (Average of top left and bottom left) & avgright (Average of top right and bottom right).
Step6: Align the solar panel.
Step7: If avgtop is greater than avgbot then increase the value of servomotor by 1 unit, with given delay.
Step8: Else If, avgbot is greater than avgtop then decrease the value of servomotor1 by 1 unit, with give delay.
Step9: (Simultaneous along with step7) If avgleft is less than avgright, then increase the value of horizontal servomotor by 1 unit, with give delay.
Step10: Else if, avgleft is more than avgright then decrease the value of servomotor2 by 1 unit, with give delay.
Step11: Goto back to step 6.
Step12: End.

**Hardware Components**

The design of any system consists of Hardware requirements and Software development. Hardware requirement is focused on the components which are used for designing the project and Software development is focused on the coding which is loaded into the hardware.

**b) Arduino Uno**

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board.

The Atmega328 has 32 KB of flash memory for storing code (of which 0,5 KB is used for the bootloader); Ithas also 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).


Figure: Arduino Uno

Table: Arduino Specifications

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| FEATURE | SPECIFICATION |
| --- | --- |
| Microcontroller | ATmega328 |
| Operating Voltage | 5V |
| Input Voltage (recommended) | 7-12V |
| Input Voltage (limits) | 6-20V |
| Digital I/O Pins | 14 (of which 6 provide PWM output) |
| Analog Input Pins | 6 |
| DC Current per I/O Pin | 40 mA |
| DC Current for 3.3V Pin | 50 mA |
| Flash Memory | 32 KB (ATmega328) of which 0.5 KB used by boot loader |
| SRAM | 2 KB (ATmega328) |
| EEPROM | 1 KB (ATmega328) |
| Clock Speed | 16 MHz |

**c) Liquid Crystal Display**

LCD screen consists of two lines with 16 characters each. Each character consists of 5x7 dot matrix. Contrast on display depends on the power supply voltage and whether messages are displayed in one or two lines. For that reason, variable voltage 0-Vdd is applied on pin marked as Vee. Trimmer potentiometer is usually used for that purpose. Some versions of displays have built in backlight (blue or green diodes). When used during operating, a resistor for current limitation should be used (like with any LE diode).

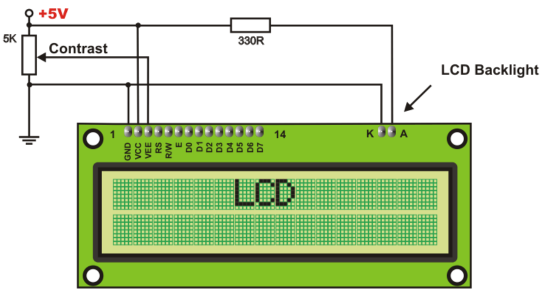


Figure: LCD Display

**c) Dc Motor**

A DC motor is designed to run on DC electric power. Two examples of pure DC designs are Michael Faraday's homopolar motor (which is uncommon), and the ball bearin motor, which is (so far) a novelty. By far the most common DC motor types are the brushed and brushless types, which use internal and external commutation respectively to create an oscillating AC current from the DC source -- so they are not purely DC machines in a strict sense.

Figure: DC Motor

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**c) ULN Driver**

The ULN2003 internally employs high voltage, high current darlington arrays each containing seven open collector darlington pairs with common emitters. Each channel rated at 500mA and can withstand peak currents of 600mA. Suppression diodes are included for inductive load driving and the inputs are pinned opposite the outputs to simplify board layout. ULN2003A is of 5V TTL, CMOS. These versatile devices are useful for driving a wide range of loads including solenoids, relays DC motors, LED displays filament lamps, thermal printheads and high power buffers. The ULN2003A are supplied in 16 pin plastic DIP packages with a copper leadframe to reduce thermal resistance.


Figure: ULN Driver

**d) Light Dependent Resistor**

Light Dependent Resistors are astoundingly significant especially in light/dull sensor circuits. Typically the protection of a LDR is high, once in a while as high as 1,000,000 ohms, however when they are lit up with light, the protection drops significantly. . Along these lines in this endeavor, LDR expect a basic part in trading on the lights in light of the power of light i.e., if the power of light is all the more (amid daytime) the lights will be in off condition. What's more, if the power of light is less (amid evenings), the lights will be exchanged on.

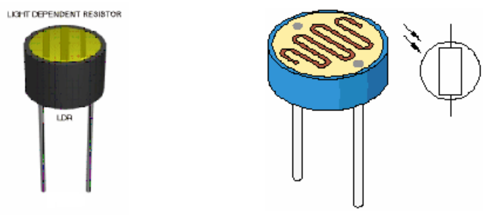


Figure: LDR Sensor

The yield of the LDR is given to ADC which changes over the simple power an incentive into relating advanced information and presents this information as the contribution to the microcontroller.

**2. RESULTS**

Finally, to make automatic dual axis movement solar tracker, we make proper connections of all the hardware, so that they work to track the sun. It was very important concern while designing the system because the slightest movement of sun could be tracked. The complete circuit used to track the sun is shown in figure. As the circuit shows we used 2 LDRs in order



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to track the sun on two axis. Each pair of LDRs is responsible for tracking the sun on each of the two adjacent LDRs are measured and that output is fed to four inputs in the microcontroller.

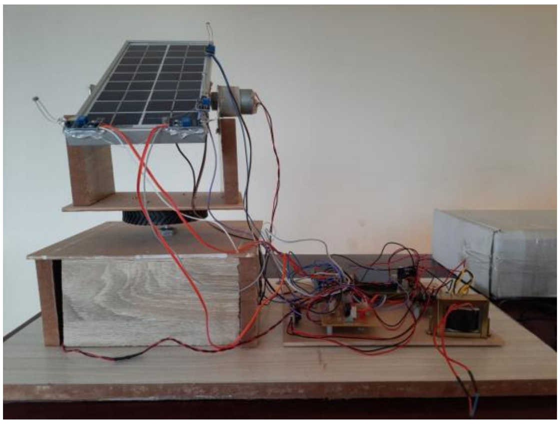

Figure: Hardware Prototype

## 3. CONCLUSION

In this paper, the goal of the project was to design and implement a small scale prototype of tip-tilt dual-axis solar tracker with basic tracking functions. Designing and implementing processes have been accordingly completed for the work of the project.

The final result was a complete design of such a system, with functionality that met the design requirements. While the project has succeeded in creating a device with basic required features, there are still considerable drawbacks and limitations with the performance of the device, as discussed in the implementation work of the project. It is possible to overcome these limitations and to improve the performance of the device in future development.

The project was a successful effort in fulfilling the purpose when I started it, that is to research and catch up with current technologies in this field of energy exploitation. It is a useful reference for those who need to develop similar systems. The knowledge and information from this project can also become the starting point for future development of several of applications.

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