# Smart and Intelligent Dual Axis Solar Tracker using Arduino Micro-controller

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***Abstract -*** *Now-a-days there is a high demand of electrical energy generated from renewable energy sources. One of the best ways is solar energy since it is inexhaustible and causes no pollution. Solar panels can be used to convert solar energy to electricity. But the challenge remains to maximize the input from sun and correspondingly maximize in the output power generated. These solar panels can be fixed type or can be rotatory type. They can be rotated in both single and dual axis. This paper deals with the implementation of Energy and Cost Effective Dual Axis Solar Tracker using Arduino along with the comparison and cost report of fixed, single and dual axis trackers in MATLAB.*

***Key Words*****: Arduino, MATLAB, Servo Motors, LDR, Solar energy**

## 1. INTRODUCTION

In the recent scenario of the world, non-renewable energy is on the verge of extinction. There is growing consumption of non-renewable energies like fossil fuels, petrol, diesel etc. If this rate of consumption remains then these resources can last only up to 100 years. So there is a need of developing the renewable energy sources like wind, sun and water. One of the best ways of utilizing the renewable energy is solar energy from the sun. We know that the sun rotates from East to West throughout the day and revolves from North to South throughout the year with respect to the Earth [1]. Fig. (1) Shows the position of the solar panel with respect to the rotation of the sun.

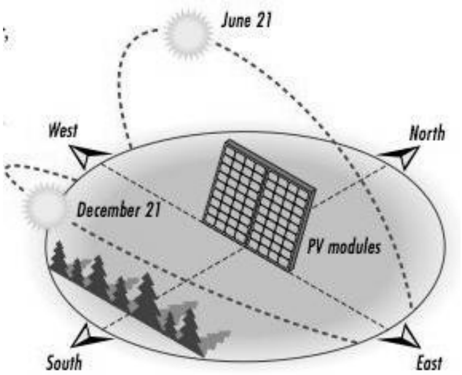


**Fig -1**. Sun's Path

Solar panels are the device which converts the sun's energy into useable electrical energy with the help of Photovoltaic cells [2]. These PV cells are combined together to give a solar panel. In many of the places solar panels are setup at a particular fixed angle also known as Fixed Axis Solar Panels (FASP). These solar panels have very low efficiency and power generated from them is also very low. In order to maximize the efficiency and output power we need to track the sun and correspondingly move the solar panels towards the direction of maximum sun rays. This can be done in two ways viz. Single Axis Solar Tracker (SAST) [3] and Dual Axis Solar Tracker (DAST). The SAST has a comparatively lower efficiency and power output than DAST but higher than FASP. Thus implementing DAST is very helpful as it has highest efficiency and power output of all the three. Also the angle of incidence on the panel should be an optimized angle. Techniques such as azimuthal angle tracking and zenith angle tracking are very useful in Dual Axis Solar Tracker [4].

## 2. PRINCIPAL OF TRACKING

In order to track the sun we need some sensors which will sense the rays of sun. The best and the cheapest method is use of Light Dependent Resistors (LDR). As shown in the Fig. (2) the resistivity of LDR decreases as the illumination increases. Also resistance decreases when light falls on them and increases when in dark [5].


**Fig -2**. Resistivity vs Illumination

As the LDR gives analog output voltage this output voltage can be processed further using microcontrollers and the corresponding output to some rotating device which can rotate the panel in either single or dual axis. The micro-controller gets all the analog voltages from the number of LDR's fixed and then selects the maximum of them. Then the panels will be moved by the servo motors towards that LDR having higher analog voltage. This process is carried out throughout the day.

## 3. BLOCK DIAGRAM REPRESENTATION

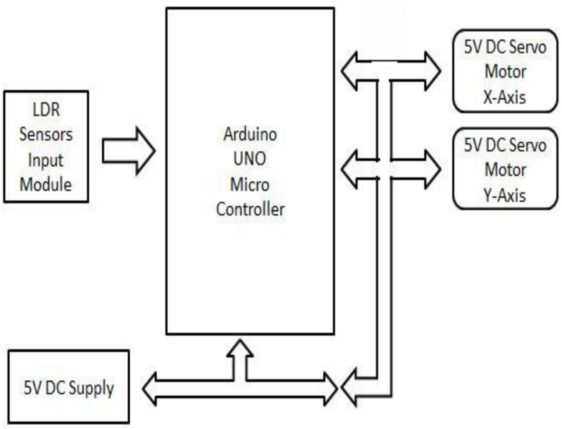


**Fig -3**. Block Diagram Representation

### 3.1. Power Supply

An unregulated 5-20 VDC (7-12V recommended) , which can be supplied via 2.1mm center positive barrel plug connector or USB cable connected to the micro-controller and servo motors.

### 3.2. LDR Sensors

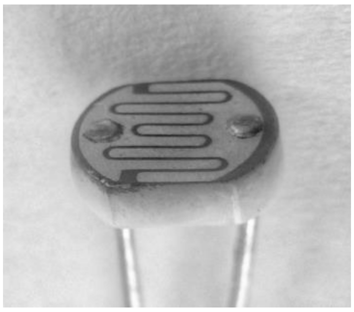

**Fig -4**. Light Dependent Resistor

As discussed in [6] the characteristic of LDR depends on the illumination (Lux). The resistivity decreases with a corresponding increase in illumination. Fig.(2) shows the structure of LDR. It consists of two electrode, a photo conductive material and two wire terminals. The LDR sensor module forms the input block for the dual axis solar tracker. 4 such LDR are used for this paper. They are arranged in four quadrants as shown in Fig.(5) viz. left top, right top, left bottom, right bottom. They sense the intensity of light incident on them and correspondingly give and analog voltage level which can be further processed by micro-controller and the front view of LDR is shown in Fig.6.

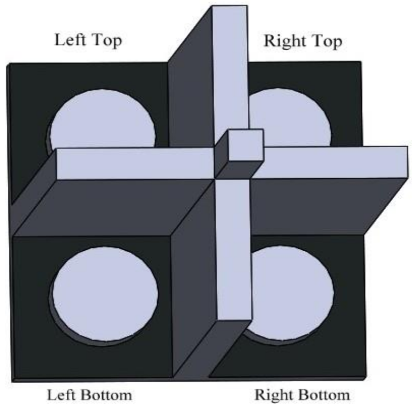


**Fig -5.**Top view of proposed LDR arrangement

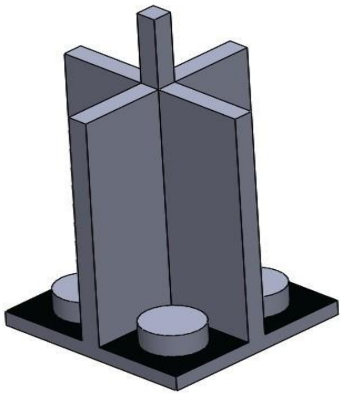

**Fig -6**. Front view of proposed LDR arrangement

### 3.3. Arduino UNO Micro-controller

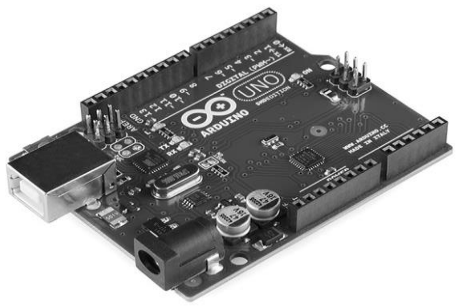

**Fig -7**. Arduino Micro-controller Board

Arduino [7] is an open-source prototyping platform based on both hardware and software. Arduino boards are available in many types and can be programmed as required using Arduino Software (IDE). Fig.(7) shows the actual Arduino micro-controller board. The main chip used is the ATmega 328which is the heart of the Arduino. The Arduino has 6 Analog and 12 Digital Input/output pins. Two pins are dedicated for serial communication, one for transmission and another for receiver. The Arduino can be powered either by USB or an external supply. Input signals from sensors can be processed and turned into output as required by sending sets of instructions to the hardware board. Here Arduino UNO Micro-controller has been used which forms the controlling section and is the heart of the system. It controls the whole tracking principle along with processing signals from input (LDR sensors) to output (servo motors).

D. Servo Motors


**Fig -8**. Servo motor

Fig.8. shows a 9g SG90 servo motor which is operated at 5V. Servo motors [8] are those motors which rotate through a certain degree of angle when pulse input is given. These pulses are provided by Arduino from its digital PWM pins. Two such servo motors are used in this prototype. One servo motor is used for horizontal axis. The other one is used for vertical axis.

## 4. HARDWARE IMPLEMENTATION

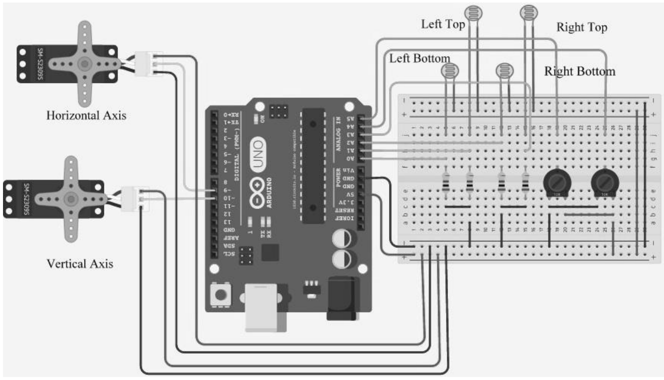


**Fig -9**. Proposed Arduino Circuit Connection

Fig.9. shows the circuit connections of the hardware prototype. The 4 LDR's are connected to the analog ports of the Arduino. The servo motors are connected to the digital PWM pulse pins. The Arduino gives PWM signals to the servo motor and according to that the servo moves a particular angle.

The schematic diagram of the above circuit is shown in Fig.10.

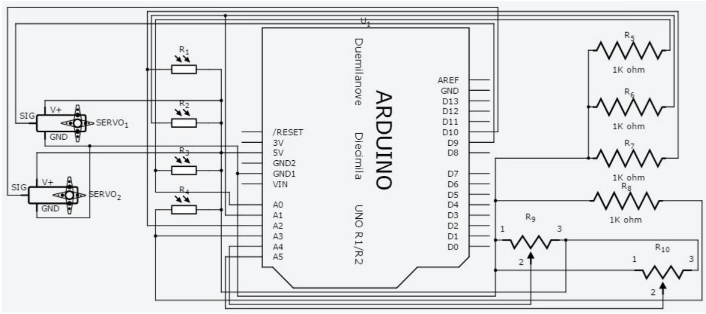


**Fig -10**. Circuit Schematic

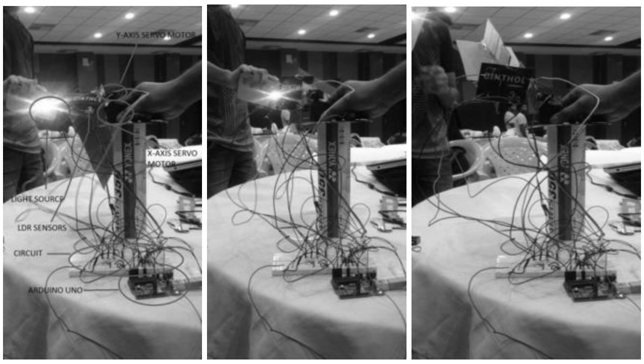


**Fig -11**. Structural and hardware implementation of Dual Axis Solar Tracker.

Fig.(11) shows the working prototype of the proposed model. It consists of two servo motors for both X-axis and Y-axis rotation [9]. The micro-controller receives signals from LDR and accordingly gives the servo motor the angle of rotation. Flashlight from the mobile is used as a light source for the LDR's. The code is coded in Arduino software and then dumped into the micro-controller. Solar panels can be used in this arrangement for implementation purposes.

## 5. WORKING CONDITIONS

As shown in Table (1) the Fixed Axis Solar Tracker works efficiently only during sunny weather. The Single Axis Solar Tracker on the other hand works efficiently during both sunny as well as partly cloudy conditions. The main advantage of the dual axis solar tracker is that it can track the sun also during partly cloudy weather conditions. Thus if weather conditions are worse we can provide signals to the arduino micro-controller and switch off the servo motors to save energy. A GPS module can be used to enable this feature thereby saving a lot of energy.

Table 1
**Table -1:** Working conditions

| Tracker Position | Sunny Weather | Partly Cloudy Weather | Cloudy Weather |
|---|---|---|---|
| Fixed Axis Solar Tracker | Yes | No | No |

| | | | |
|---|---|---|---|
| Single Axis Solar Tracker | Yes | Yes | No |
| Dual Axis Solar Tracker | Yes | Yes | Yes |

### 5.1. Comparison

For comparing the three types of solar tracker viz. Fixed Axis Solar Tracker, Single Axis Solar Tracker, Dual Axis Solar Tracker the power output throughout the day was taken from [10] as shown in Table (2). The data was plotted on MATLAB graphically as shown in Fig.(12).

**Table -2:** Power Output of three types of solar tracker

| TIME | FIXED AXIS | SINGLE AXIS | DUAL AXIS |
|---|---|---|---|
| 8:00 | 0.074 | 0.0045 | 0.92 |
| 9:00 | 0.78 | 0.54 | 18.99 |
| 10:00 | 15.04 | 19.40 | 30.41 |
| 11:00 | 19.76 | 21.38 | 32.01 |
| 12:00 | 19.19 | 19.26 | 33.22 |
| 13:00 | 20.17 | 26.68 | 34.16 |
| 14:00 | 15.73 | 17.42 | 28.87 |
| 15:00 | 16.70 | 17.88 | 26.72 |
| 16:00 | 7.81 | 18.70 | 25.76 |
| 17:00 | 0.75 | 8.08 | 23.61 |
| 18:00 | 0.63 | 0.84 | 6.98 |

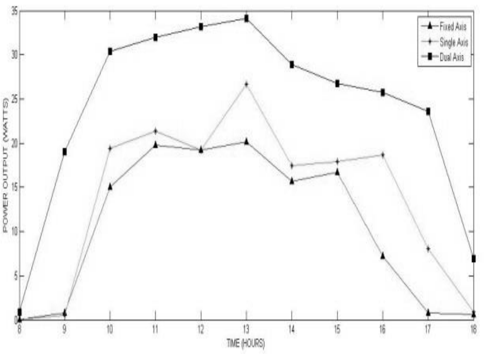


**Fig -12.** MATLAB simulation of efficiency of three different solar trackers.

It is evident that throughout the day the dual axis solar tracker gives highest output power followed by single axis solar tracker and lastly fixed axis solar tracker. With the help of the power output, efficiencies of the solar tracker can be found out in MATLAB [11].

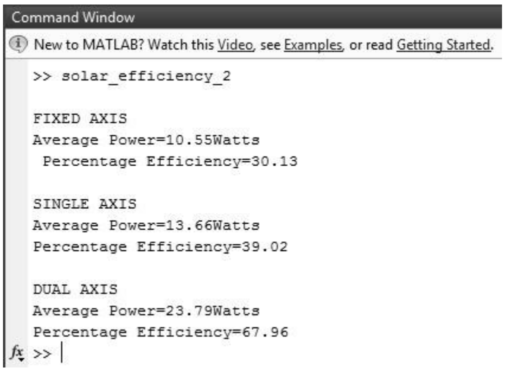


**Fig -13**. Efficiency Calculation

According to the MATLAB simulation the fixed axis has 30% efficiency with an average power of 10.55 Watts. Whereas the single axis has an efficiency of 39% with average power 13.66 Watts and dual axis has efficiency as high as 67% with average power 23.79 Watts is shown in Fig.(13).

## 6. COST ANALYSIS

The proposed dual axis solar tracker produces a greater power output and energy than the fixed axis and single axis solar tracker. Thus the annual excess energy in Kilo Watt Hour generated by the dual axis solar tracker as compared to single axis and fixed axis can been found out. With this excess energy the annual savings over fixed axis and single axis can be found out. The MATLAB simulation is as follows.

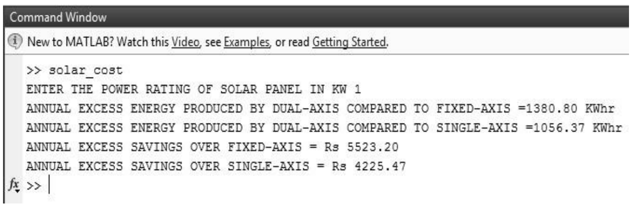


**Fig -14.** MATLAB simulation of Excess Energy and Annual Savings.

Considering that a 1 Kilo Watt solar panel is used in all the solar trackers. The annual excess energy generated by the dual axis as compared to fixed axis is 1380.80 KWHr. Whereas as compared to single axis it is 1056.37 KWHr. Considering 1KWHr of electricity costing around RS 4 in India, the annual savings by implementing dual axis over the fixed axis will be RS 5521.20. And if it compared to single axis savings will be around RS 4225.47. From the excess energy generated by the dual axis solar tracker, on an average 10 more classrooms can be powered for one hour in a single day is shown in Fig.(14).

The initial investment required for setting up the hardware will be around RS 20,000. This money can be repaid in approximately two years from the cost of electricity saved through the panels. Thus this is a short term investment and a long term profit project. Also it is eco-friendly and has very low maintenance cost and complexity.

Assuming average consumption of electricity per month of a house to be 220 units (KWhr). We can power 4 such houses for one month with the help of excess energy generated from the 1KW dual axis solar panel.

## 7. CONCLUSION

The proposed dual axis solar tracker can track the rays of sun in an effective way as compared to other methods currently in use. It gives higher output power as well as higher efficiency. It can also operate in partly cloudy weather conditions. Initial setup cost is high but on the long run it is very much cost effective.

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