# Comparison of open circuit voltage generated by tracking solar panel and static solar panel using arduino board

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## Abstract

This paper represents the comparison of the voltages generated by the tracking and static solar panels. The work also aims to design and fabrication of a cheap and efficient tracking device. This device comprises of hardware and software. A rigid mechanical structure with nut and screw as the transmission is developed. 4 LDRs and DC motors are employed, which are cheap and less power consuming. As far as the software concerns, an open source microcontroller "Arduino UNO" board is used because of their simplicity and cost effectiveness. This Sun tracking device with a PV panel installed on it, is placed outside at the roof of the building along with a static solar panel. Output voltages generated from both panels are recorded in SD card through data logger in Arduino UNO. This real-time data shows the difference in amplitude of both the signals. Voltage of rotating panel is more than static one resulting that the tracking device can increase the efficiency of the panel by exposing the PV panel more to the sun light. Hence this setup proves that the solar panel with tracking system generates more energy than solar panel without tracking system.

*Keywords:* Solar Tracker, LDR, PV Panel, Arduino UNO Board.

## 1. Introduction

Energy requires for many ways in daily life. There are lots of resources of power generation. Around 85% of power is produced from fossil fuels (Anuraj & Gandhi, 2014). They are depletion in nature. Hence renewable energy resources are required. Wind energy, geothermal energy, tidal energy and solar energy are some of the most renewable energies. Solar energy is used most. It is available almost at every location. Solar energy can be utilized in two forms of energies, which are thermal energy and electrical energy. These energies can be reached by using some devices. Transformation of solar energy into electrical energy can be done by using PV (photovoltaic) cells. Sun light falls on the PV panel generates DC voltage. This voltage has a direct connection with the intensity of the light incidents on solar panel. Intensity of Incident Sun light depends on the incidence angle between incoming light and a normal to photovoltaic (PV) panel as shown in Figure 1. The relation of power (P) and angle of incidence ( ) is shown in eq. (1).

Sunlight strikes the panel at an angle . Let the sunlight is striking at a constant intensity ( ), the available sunlight to the solar cell for power generation (P) can be calculated as:

$$P = A. \, .Cos \tag{1}$$

where, 'A' is limiting conversion factor, because 100% of incidental sunlight cannot be converted. Hence, maximum power will generate only when    = 0, i.e. the Sunlight hits the PV cell along the normal. When the sunlight falls on an angle rather other than 90 degrees, less power will generate. If the panel is fixed, there will significantly power loss during the day. It is due to the rotation of the earth in path. Because of the changing direction of the Sun. Along this, value of    changes continuously. The power loss will be there for non-zero value of   . Hence the angle of stationary panel should be at optimum position where the panel can generate maximum power (Guo et al., 2017).
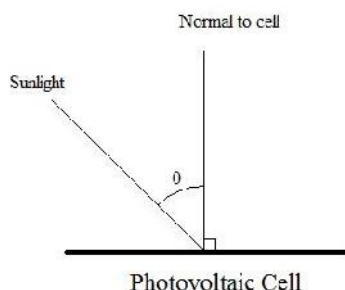


**Figure 1**. Angle of incidence (Sharma & Sharma, 2017)

## 1.1. Need of Solar Tracker

Tracking system preserves the angle of incidence equal to 90. It increases the output of solar power plants by 25% to 40%, depending on the natural features of location. Two types of solar tracking devices are there. Single axis tracker (Das et al., 2016) and another is dual axis tracker. Gupta (2019) worked on simulation of single axis tracking and resulted 31% increase power generation compared to static panel. Single axis tracker increases power output by 26%, while a dual axis tracker can increase output by 32% (Deb & Roy, 2012). Out of these two, dual axis tracking gives better results (Hong et al., 2016; Fathabadi, 2016). Single axis tracker tracks the Sun from east to west only, whereas dual axis tracker tracks the Sun by altitude (up/down) and (east/west), it is because of the movement of the Sun throughout the day. Mousazadeh et al. (2009) calculated the power generated by tracking close to an ideal 57%.

Tracking system is composed of electronic sensors and mechanical mechanism. Mechanical mechanism supports the panel and also help to rotate the panel and this rotation is guided by electronic sensors. Many principles and methods can be used in sun tracking (Mousazadeh et al., 2009). The electronic controlling devices can be classified into three units, those are microprocessor control unit (Arsalan, 2013), passive control unit and electro-optical control unit. If the system works without any electronic device is called as passive control unit. Programming and/or geological data is required in microprocessor control unit. The electro optical control unit uses solar detecting devices, which are sensitive to Sun light. Light Dependent Register (LDR) is one of them. Electro optical control device is used in this work. Microcontrollers like Arduino Uno board can be used separately for controlling the motors. Input from the sensors like LDRs is fed in microcontroller and output comes out based on algorithms. These controllers act as a brain for the device (Mandal & Singh, 2017).

## 1.2. Data Acquisition

Data coming from solar panel should be recorded to explain the existence of solar tracker. It is in the form of voltage, current and power. Data recorded from tracking and stationary solar panels should be compared. Comparison of static solar panel with single axis and dual axis solar tracking panels can also be conducted (Ponni & Ranjitha, 2008). Single and dual axis solar trackers can also be compared with each other. There are various methods of data acquisition. Wireless technology is also there (Seal, Shirke, Shewale, Sirsikar, & Hankare, 2014). IoT technology can also be used for this as Mohd Said et al. (2020) used in his work. Data acquisition cards are available in the market. Arduino board is cheaper and easily available. It is open source device. It can be used for this (Babrekar et al, 2016). Arduino can be bridge with LabVIEW software. LIFA is used in this. Data from the sensors are fed in to LabVIEW software through Arduino and output is generated through algorithms (Pradeep et al., 2014). It will give user friendly interface (Mandal & Singh, 2017).

Othman et al. (2013) used servo motors in the tracking device. Morón et al. (2017) used stepper motors and linear actuators for the rotation. Servo and stepper motors are costlier than ordinary DC motors and more power consuming too. Prospero et al. (2019) worked on Solar Energy Harnessing Optimization Algorithm using Arduino Nano with micro servo motors and resulted increase in 29% more radiant energy capture. Ulaganathan et al. (2014) used MPPT method in Sun tracking device. This method is used with Arduino microcontroller. They have done modeling and simulation using MATLab and Simulink. Maximum and constant power comes out is achieved. Chowdhury et al. (2019) worked on close loop system in which they proved that the accuracy of the AA algorithm comparable to other algorithm in measuring the sun position.

   This research work aims to compare the output of tracking and static PV panels by developing a rigid tracking device which is less costly and more energy efficient. Ordinary DC motors are used which are cheaper than servo motors and consumes less power. Electronic circuit does not contain any microcontroller, which decreases the overall cost and also eliminates the programming. Arduino UNO board is used only for real time data recording. A nut and screw assembly is used for the transmission of power from motor which gives the self-locking to the panel rotation about horizontal axis. Setup description is discussed in the next paragraphs.

## 2. Experimental Setup

A dual axis solar tracker is made-up for experimentation. This setup was earlier made-up by Sharma and Sharma (2017). They also made it for both rotations i.e. about horizontal and vertical axes. Mechanism for rotation about horizontal axis is remained same but some modifications are done in mechanism of rotation about vertical axis to decrease the degree of complexity and the cost of the setup. Casters are used at the place of ball bearings and chain and sprocket mechanism is removed, motor attached directly. Details of fabrication of experimental setup are as follows.

Setup is divided mainly into two parts:
- Mechanical Mechanism
- Electronic Circuit

### 2.1. Mechanical Mechanism

The rotation of solar panel depends on the position of Sun. Two DC Motors of less rpm, motor 1 and motor 2 are required for the rotation. Motor 1 provides rotation about horizontal axis and motor 2 for rotation about vertical axis. Two bearings are used at the ends of the threaded rod which is used to rotate the panel about horizontal axis shown in figure 2. These bearings also bear the load and reduce the friction. Casters are used to rotate the panel easily about vertical axis as shown in figure 2. Whole setup rests on casters. Complete setup rotates about vertical axis.



**Figure 2.** Threaded bar supported in ball bearings and casters to support and rotate whole mechanism about vertical axis

### 2.2. Electronic Circuits

Electronic circuit is used to make the setup automatic. Components used in the circuits are LDRs, transistors, diodes, IC, presets and resistors. Circuits are fabricated on PCBs. Electronic circuits are used to give signals to the motors. Every motor is connected with individual circuit. Hence two circuits are required for two motors. Here LDRs work as sensors. Two LDRs connects with a single circuit. These LDRs are fixed at the opposite ends of the panel. Differential of light intensity falling on these LDRs generates a signal through the circuit to run the motors to rotate the PV panel in the required position such that equal magnitude of light would fall on both the LDRs. Circuit diagram is shown in Figure 3. LDRs are connected to IC. Motor is connected with IC through an arrangement of transistors and diodes. Presets are used in between the terminals of the IC. 12 V DC voltage is required which is extracted from rechargeable battery. Fabricated circuit on PCB is shown in Figure 4.
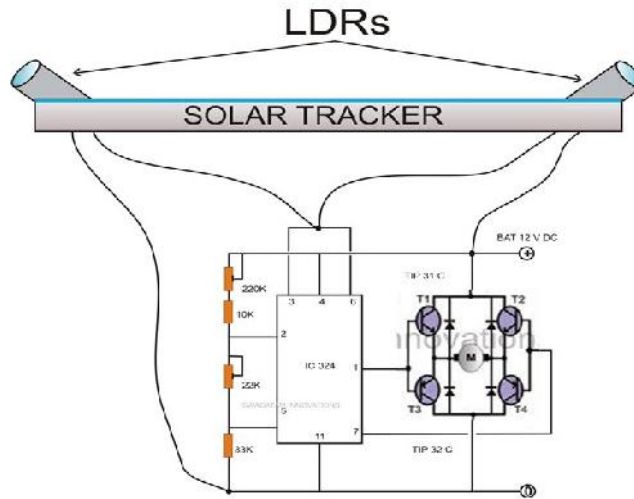
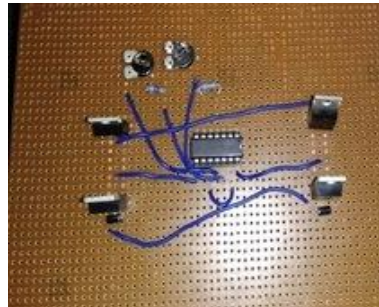**Figure 3.** Circuit diagram (Lamar Stonecypher, 2011)



**Figure 4**. Fabricated circuit on PCB

## 2.3. Assembly of the setup

LDRs are installed at the mid of every side of the PV panel. LDRs on the side edges work for the rotation about vertical axis and LDRs on upper and lower edges work for horizontal axis rotation. Both the circuits are placed on the setup as shown in figure 5. Setup requires calibration. It was done in a dark room. Two presets are there in a single circuit. These are tuned to stop the running of the connected motor. It should be ensured that motor should not run while it is placed in the dark. In dark room, intensity of light on all LDRs remains the same.
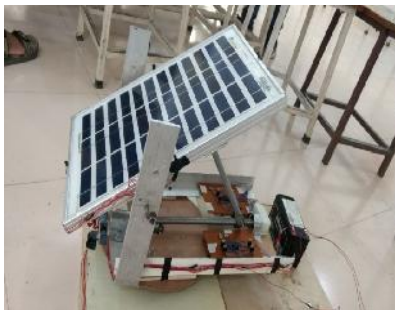


**Figure 5.** Experimental Set-Up

Complete setup is a combination of electronic and mechanical components which work together to form dual axis solar tracking device as shown in figure 5. Battery is charged by the solar power and a negligible amount of power is utilized in running of motors.

**2.4. Testing of the setup**

Testing process is as follows:
1.  Take a light lamp as a source of light (Sun). Rotation of the panel depends on the position of this light source.
2.  Keep the lamp in the center. Solar panel does not move until the light source remains at the center.
3.  Move the lamp in the right direction. Panel will track the light and stops at the position where the lamp would be in the center of the panel. Panel moves to that direction in which the light sources moves.

Hence the setup can be tested by moving the light source in arbitrary direction. Performance of the setup can be justified by the degree of tracking of the light source.

**3. Results and Discussion**

Two solar panels of 8W, 12V were placed in Sun at 11:30 am on 12[th]April 2018. One panel was stationary, making an angle of 20 degree with earth surface and facing towards south. Another panel was engaged with tracking system which was rotating along Sun. Open circuit voltage was recorded in data logger through Arduino board. Experiment was conducted from 11:45 am to 12:35 pm. This experiment was performed for 50 minutes. Readings of voltage coming from the experimentation were plotted on graph which is shown in Figure 6. As shown in above plotted graph, voltage produced by the tracking PV panel is more than the voltage generated by stationary panel at every instant. Average voltage generated by the stationary panel tracking panel are 20.81 V and 23.21 V respectively. Hence panel with tracking generated 2.40 V more than stationary solar panel. This is because of the more radiant energy falls on the panel mounted on tracking device. Hence more power generates.

This experiment was conducted in the peak time and it was a summer day. Average voltage difference recorded was 2.40 V. This will be more useful in morning and evening time and in winter days when Sun light comes on earth for short period and with less intensity. Tracking devices are also more beneficial in those areas, where the Sun appears for less time period in a day like mountainous area (Chitturi et al., 2018). For example, at a place, Sun appears for 4 Hours in a day. In that short period of time, if panel is kept facing the Sun whole time, then only more power can be generated by the panel. And this is possible only by using tracking system.
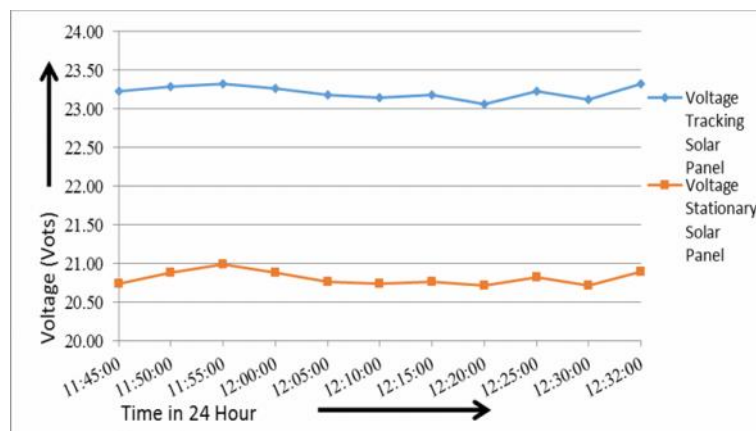


**Figure 6.** Voltage – Time relation of tracking and stationary plates

**4.   Conclusions**

In conclusion, from the above discussion, the tracking solar panel generates more power than stationary solar panel. Hence, the tracking system can decrease the overall cost of the solar power plant by decreasing the quantity of PV panels for a constant power generation. In addition to this, it can also be concluded that the components used in this device work properly which fulfil another objective of the work. This leads to the decrease in the cost. In the future, in order to decrease the cost further, the design of the device can be improved. Some safety switches can also be employed which will act as a guard for the device in case of failure. Some techniques like genetic algorithm can be implemented.

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