"Study and analysis of Arduino based solar tracking panel"

Byregowda K. C [1], Ranjith.V [2], Venkatesh reddy [3], Shashikantha N [4]

[1]Assistant professor, Department of Mechanical Engineering, Dr. AIT, Bangalore, India.
[2]Assistant professor, Department of Mechanical Engineering, Dr. AIT, Bangalore, India.
[3]Associate professor, Department of Mechanical Engineering, Dr. AIT, Bangalore, India.
[4]Associate professor, Department of Mechanical Engineering, Dr. AIT, Bangalore, India.

Abstract - *The efficiency of the solar panels can be increased by studying different solar radiation tracking mechanism, this work comprising the study of different types of tracking mechanisms and analysis is completely a new concept using mechatronics. The problem that is posed is the implementation of a system which is capable of enhancing production of power by 30-40%. The control circuit is implemented by the microcontroller. The control circuit then positions the motor that is used to orient the solar panel optimally. The project was designed to address the challenge of low power, accurate and economical microcontroller based tracking system which is implemented within the allocated time and with the available resources. It is supposed to track the sun's movement in the sky during daylight and save much needed power, sleep at night. There is implementation of an algorithm that solves the motor control that is then written into C- program on Arduino IDE.*

Key Words: Arduino, microcontroller, solar panel, algorithm, efficiency, maximum power point tracking, LDR.

1. INTRODUCTION

Nowadays, depletion of conventional energy resources led many researchers to look into the renewable energy source. Among all the energy resource solar energy is very promising one. Solar technologies use the sun for provision of heat, light and electricity. The energy potential of the sun is immense. Despite the unlimited resource however, harvesting it presents a challenge because of the limited efficiency of the array cells. Climate change is a subject that has been discussed profusely these recent years. The effects that fossil fuels, among other things, have had on the environment have led to many scientists trying to find alternatives, more environmentally friendly fuels and cleaner sources of energy. Solar energy is clean and available in abundance.

The main aim of the present work is to design a system that could track the sun for a solar panel. This has been achieved through using light sensors (LDRs) that are able to detect the amount of sunlight that reaches the solar panel. The values obtained by the LDRs are compared. Also seeks to identify away of improving efficiency of solar panels. Solar tracking is used. The tracking mechanism moves and positions the solar array such that it is positioned for maximum power output. Other ways include identifying sources of losses and finding ways to mitigate them. Maximum power point tracking (MPPT) is the process of maximizing the power output from the solar panel by keeping its operation on the knee point of P-V characteristics. Solar tracking is a system that is mechanized to track the position of the sun to increase power output by between 30% and 60% than systems that are stationary. Single axis trackers are a better option for places around the equator where there is no significant change in the apparent position of the sun. The level to which the efficiency is improved will depend on the efficiency of the tracking system and the weather.

2. Types of Solar Trackers and Solar Tracking Techniques.

Modern solar tracking methods and techniques are

Single Axis Solar Tracking System This is method is usually used for solar trackers aimed to be used in the tropics where the focus is to track the angle of altitude (angle of tilt) of the sun along a single axis. A single linear actuator is used, such as a motor to drive the panel according to sun movements. A set of two LDRs on opposite sides of the solar panel may be used to measure the intensity of the solar irradiation by measuring the voltage drop across them which is then compared by a drive circuit until the two LDR voltages are equal and the motion of the panel is stopped. This way, the solar panel is always oriented, normally to sun irradiation.

Dual Axis Solar Tracking System This method is mainly designed for localities outside the tropics or areas beyond 10[illegible] and 10[illegible] of Equator. In this technique, both angle of azimuth and angle of Tilt of the solar tracker are used to track the sun movements throughout the year. Consequently, a set of two actuators, usually motors is used to move the solar panel accordingly by receiving voltage control signals from a set of four LDRs (two on opposite sides of solar panel) and when the voltage drop on all the four LDRs is equal then the panel is experiencing the maximum solar irradiation and therefore the motion stops. This ensures the solar panel is at right angles with sunlight at all times.

Active Solar Tracking This technique involves the continuous and constant monitoring of the sun's position throughout daytime and when tracker is subjected to darkness it stops or sleeps according to its design. This can be done using of light sensitive sensors, such as photo resistors(LDRs) whose voltage output are input into a microcontroller which then drive actuators (motors) to adjust the solar panels position.

Passive Solar Tracking Passive trackers use a low boiling point compressed gas fluid driven to one side or the other to cause the tracker to move in response to an imbalance. This method involves trackers that determine the Sun's position by means of a pressure imbalance created at two ends of the tracker. This imbalance is caused by solar heat creating gas pressure on a low boiling point compressed gas fluid that is driven to one side or the other which then moves the structure.

Chronological solar tracking Chronological tracker can counteract rotation of the earth by turning or rotating at the same speed as the earth relative to the sun around an axis that is parallel to the earths. To achieve this, a simple rotation mechanism is incorporated which enables the system to rotate throughout the day in a predefined manner without considering whether the sun is there or not. The system turns at a constant speed of one revolution per day or 15 degrees per hour. These trackers are simple but potentially very accurate.

3. Numerical analysis of fixed and tracking collectors

Solar collectors can harness the radiant energy either by fixed or movable collectors. Fixed collectors are installed on places that have maximum intensity of sunlight and at good angle in relation with the sun. When using these collectors it is important to know the position of the sun at various seasons and time of the year.

The energy per unit area is calculated for the whole day neglecting the influence of atmospheric condition is given by

$$dW = IS.dt \text{ kWh/m}^2$$

Where S is the projection area on the area that is perpendicularly oriented to the direction of radiation is given by $S = S_o \cos\theta$

θ is the changes in the interval $(-\pi/2, +\pi/2)$ during the day

ω is angular velocity of the sun as it moves across the sky is given by

$$\omega = 2\pi/T = 7.27\times10\text{-}5 \text{ rad/s}$$

For tracking collectors, theoretical extracted energy is calculated assuming that maximum radiation intensity $I=1100\text{W/m}^2$ is falling on the area that is perpendicularly oriented to the direction of radiation. For tracking collectors, if atmospheric influence is neglected, the energy per unit of area for an entire day is given by

$$W = IS_ot = 4.75 \,\square 107\text{W}, = 13.2 \text{ kWh/m}^2 \text{ day.}$$

Comparing the theoretical results for the two cases, more energy is obtained from the second case, for the tracking collector. However, as the rays of the sun travel towards the earth, they go through the thick layers of the atmosphere in both of the cases. That notwithstanding, the tracking collector has more exposure to the sun's energy at any given time.

3.1 Efficiency of solar panels

The efficiency is the parameter most commonly used to compare performance of one solar cell to another. It is the ratio of energy output from the solar panel to input energy from the sun. In addition to reflecting on the performance of solar cells, it will depend on the spectrum and intensity of the incident sunlight and the temperature of the solar cell. As a result, conditions under which efficiency is to be measured must be controlled carefully to compare performance of the various devices. The efficiency of solar cells is determined as the fraction of incident power that is converted to electricity. It is defined as:

$$P_{max} = V_{OC} I_{SC} FF \,\eta - \frac{V_{OC} I_{SC} FF}{P_{in}}$$

Where V_{OC} is the open-circuit voltage
I_{SC} the short-circuit current
FF is the fill factor
η is the efficiency

The input power for efficiency calculations is 1 kW/m^2 or 100 mW/cm^2. Thus the input power for a 100 $\square$100 mm^2 cell is 10 W.

3.2 Design and Implementation

The Concept of Using Two LDRs is to stable position is when the two LDRs having the same light intensity. When the light source moves, i.e. the sun moves from west to east, the level of intensity falling on both the LDRs changes and this change is calibrated into voltage using voltage dividers. The changes in voltage are compared using built-in comparator of microcontroller and motor is used to rotate the solar panel in a way so as to track the light source.

Servo motors are used for various applications. They are normally small in size and have good energy efficiency. The servo circuitry is built inside the motor unit and comes with a positional shaft that is fitted with a gear. The motor is controlled with an electric signal that determines the amount of shaft movement.

Components of the servo motor: The servomotor consists of three main components; a small DC motor, a potentiometer and a control circuit. Gears are used to attach the motor to the control wheel. As the motor rotates the resistance of the potentiometer changes so the control circuit can precisely regulate the amount of movement there is and the required direction. When the shaft of the motor is at the ed position, power supply to the motor is stopped. If the shaft is not at the right position, the motor is turned in the right direction. The desired position is sent through electrical pulses via the signal wire. The speed of the motor is proportional to the difference between the actual position and the position that is desired. Therefore, if the motor is close to the desired position, it turns slowly. Otherwise, it turns fast. This is known as proportional control.

Servos are sent through sending electrical pulses of variable width, or pulse width modulation (PWM), through the control wire. There is a minimum pulse, maximum pulse and a repetition rate. Servos can usually turn only 90 degrees in either direction for a total of 180 degrees movement. The neutral position of the motor is defined as that where the servo has the same amount of potential rotation in both the clockwise and counter-clockwise direction. The PWM sent to the motor determines the position of the shaft, and based on the duration of the pulse sent through the control wire the rotor will turn to the position that is desired.

The servo motor expects to see a pulse after every 20 milliseconds and the length of the pulse will determine how far the motor will turn. For instance, a 1.5ms pulse makes the motor to turn in the 90 degrees position. If the pulse was shorter than 1.5ms, it will move to 0 degrees and a longer pulse moves it to 180 degrees.

For applications where there is requirement of high torque, servos are preferable. They will also maintain the torque at high speeds, up to 90% of the rated torque is available from servos at high speeds. Their efficiencies are between 80 to 90%.

A servo is able to supply approximately their rated torque for short periods of time, offering enough capacity to draw from when needed. In addition, they are quiet, are available in C and DC, and do not suffer from vibrations.

Microcontroller is a single chip microcomputer made through VLSI fabrication. A microcontroller also called an embedded controller because the microcontroller and its support circuits are often built into, or embedded in, the devices they control. A microcontroller is available in different word lengths like microprocessors (4bit,8bit,16bit,32bit,64bit and 128 bit microcontrollers are available today).

4. Results and analysis

Results were taken for two days, recorded and tabulated. The outputs of the LDRs were dependent on the light intensity falling on their surfaces. Arduino has a serial that communicates on digital pins 0 (RX) and 1 (TX) as well as with the computer through a USB. If these functions are thus used, pins 0 and 1 can be used for digital input or output.

Arduino environment's built in serial monitor can be used to communicate with the arduino board. To collect the results, a code was written that made it possible to collect data from the LDRs after every one hour. The values from the two LDRs are to be read and recorded at the given intervals.

The LDRs measure the intensity of light and therefore they are a valid indication of the power that gets to the surface of the solar panel. As a result, by measuring the light intensity at a given time, it will be possible to get the difference in efficiency between the tracking panel and the fixed one. The light intensity is directly proportional to the power output of the solar panel.

A code was written that made it possible to obtain readings from the two LDRs at intervals of one hour. The EEPROM came in handy in this. It is the memory whose values are kept when the board is turned off. The ATmega 328P has 1024 bytes of EEPROM.

To get the values at the end of the day, the Arduino board was used to connect the microcontroller to the computer. The RX and TX pins are used for the connection. The code for reading the values that were recorded is loaded into the microcontroller. The various values are obtained and converted into volts. The Vcc to the microcontroller and the LDRs is 5 volts. The Atmega 328P has 1024 voltage steps and 5 volts. When they are converted into digital values, the values will be in the range of 0-1023. The conversion is done using the relation below.

$$LDR\ Output = \frac{Digital\ equivalent\ output * 5}{1023}\ \text{Volts}$$

Time	LDR readings for a fixed panel		LDR readings for a tracking panel	
	LDR 1	LDR 2	LDR 12	LDR 22
0630 hrs	0.196	0.176	1.477	1.487
0730 hrs	0.249	0.210	1.804	1.839
0830 hrs	0.225	0.196	2.757	2.933
0930 hrs	0.723	0.567	3.631	3.783
1030 hrs	0.733	0.816	3.900	3.798
1130 hrs	3.211	2.297	3.910	3.969
1230 hrs	4.888	4.941	4.990	4.990
1330 hrs	3.803	3.910	4.985	4.990
1430 hrs	3.456	4.057	4.976	4.985
1530 hrs	3.930	3.846	4.941	4.892
1630 hrs	1.999	1.544	4.824	4.594
1730 hrs	1.090	1.144	3.128	2.981
1830 hrs	0.718	0.787	0.982	0.968

Table 1-LDR readings on 22nd of December 2019

Time	LDR readings for a fixed panel		LDR readings for a tracking panel	
	LDR 1	LDR 2	LDR 12	LDR 22
0630 hrs	0.679	0.489	1.477	1.487
0730 hrs	0.792	1.061	2.804	2.839
0830 hrs	1.779	1.672	3.203	3.990
0930 hrs	3.167	1.199	3.990	3.990
1030 hrs	3.421	3.226	4.130	4.149
1130 hrs	4.604	3.208	4.500	4.590
1230 hrs	4.990	4.980	4.990	4.990
1330 hrs	4.980	4.990	4.888	4.990
1430 hrs	4.888	4.941	4.976	4.985
1530 hrs	4.413	3.878	4.941	4.892
1630 hrs	3.935	3.824	4.873	4.790
1730 hrs	2.639	2.639	3.964	3.940
1830 hrs	1.569	1.031	2.708	2.815

Table 2-LDR readings on 28 th of December 2019

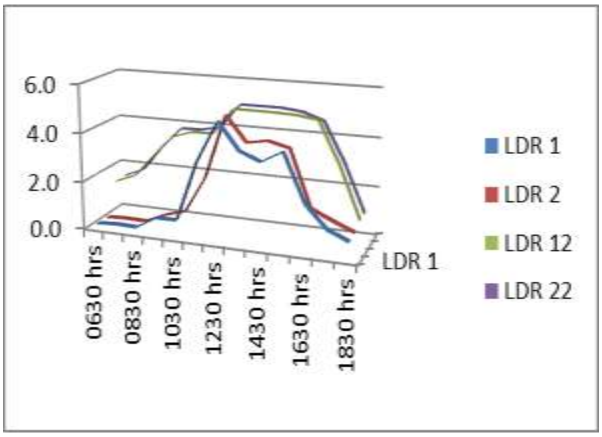

Figure 1-LDR readings on 22 nd of December 2019

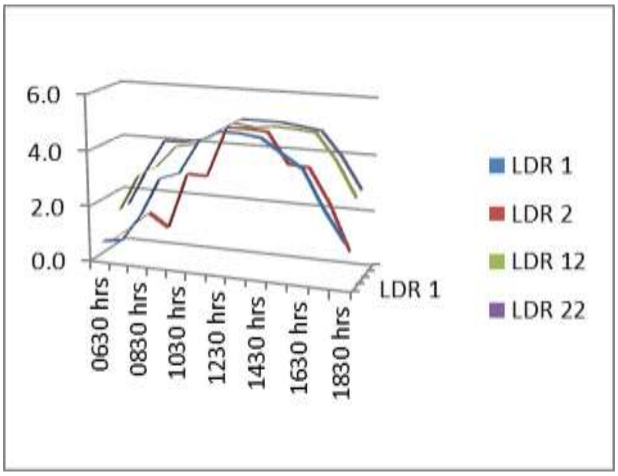

Figure 2-LDR readings on 28 th of December 2019

From the analysis of the graph and table it is observed that energy stored by the LDR 12 and LDR 22 used in tracking panel is higher than the LDR 1 and LDR 2. This increase in the energy stored is due to the expose of the solar panel throughout the day and the panel normal to the solar radiation. From Table 1 and 2, it can be observed that at the time between 1130 hrs to 1330 hrs the readings of the tracking panel and fixed panel are almost same. Also observed that, at 0630 hrs the energy stored is minimal 0.196 for LDR1 and 1.477 for LDR 12, which is comparatively higher.

5. Conclusion

The objective of the work is to improve the efficiency of solar panel using tracking mechanism. Tracking mechanism controlled by the implementation of an algorithm that solves the motor control that is then written into C- program on Arduino IDE. Literature and present study, it is seen that tracking of solar energy contributes to significant understanding of multi axial tracking, in turn it will improve the efficiency of the solar panel.

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