Single Axis Solar Tracking System

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Abstract
This paper is about the design and development of a microcontroller based solar tracking system. Solar energy is rapidly becoming an alternative means of electrical source in Kenya and all over the world and the solar energy becomes profitable when the solar rays are tracked with its maximum efficiency. The best way to get the maximum power output of solar array is by sun tracking. Usually, solar panels are steady and always the front faces the direction the sun rises from and it evident from the stationary mounted panels we see on buildings and other solar plants, this causes less amount of light incident on the panel. When we use the solar tracker system, it will move in the direction of the sun and get more amount of light incident. The great benefits of solar energy is that it is sustainable, highly reliable and requires little maintenance. Therefore, came up a system that deals with the design and construction of solar tracking system, whereby the solar panel follows the sun as it moves. The project is based on a microcontroller which controls the system by communicating with sensors and motor based on movement of the sun, the system employs light dependent resistors that will vary their resistance depending on the light intensities, light dependent resistors give output to the Arduino every time and Arduino processes the data and sends a control signal to the motor. Through the design, implementation, testing and results of the project, an efficient way of increasing the production of solar power is demonstrated.
Keywords: Photovoltaic System; Tracking System; LDRs; Light Intensity

1. Introduction

Energy crisis is becoming the most important issue to turn focus to in today's world as we are trying embrace technology and also to maintain a stable supply of energy to the increasing population

We need energy in various forms such as heat, light and sound. Due to the new developments in technology it has made it possible to convert electrical energy to any other form of energy. Therefore, giving electrical energy an important position in the today's world. The running of the modern world industrial structures depends on the low cost and also uninterrupted supply of electricity. However, as the supplies of fossil fuels are depleted in the nearby future and are become increasingly expensive day by day, the use of renewable energy resources that are cheap and freely available in nature will be gaining priorities since the conventional energy resources are not only becoming limited but also are prime culprit for environmental pollution.

Renewable resources of energy are now getting priorities and solar energy being the one of them is rapidly gaining a lot of focus as an important means of expanding the renewable energy uses and maximize on energy supply since it produces less pollution and the costs of fossil fuels energy are rising day by day, while the cost of solar arrays is decreasing. Solar tracker is an automated solar panel that actually follows the sun to increase the amount of power production by the PV panels. It's evident from studies and researches conducted that a solar panel converts 25% – 35% of energy incident on it to electrical energy.

The use of a solar tracking system is necessary to increase the efficiency of the solar panel. Solar trackers are the most appropriate and technology that increases the efficiency of the solar panel by keeping the panels always aligned with the sun.

2. Literature Survey

The main objective was to design and implement a system that will make solar as a renewable source of energy to be considered not as an alternative power supply source but rather a most important and readily available power source. This was to be accomplished by increasing the amount of power produced by solar panels at lower cost.

2.1 Solar Tracking Techniques

There are different types of solar tracking techniques and can be classified according to several criteria;

Classification of tracking systems can be made depending on the number of different rotation axes and since solar tracking implies moving the solar panel with the help of a control system, single-axis tracking systems seem to be the best solution for solar power plants. Another classification of solar tracking systems can also be made depending on the type of PV panel orientation. Another method of the solar tracker classification refers to the type of activity and according to this method we can be able distinguish active from passive solar trackers (Sabry, 2013).

2.2 Photovoltaic cell principle

Photovoltaic (PV) system is well a recognized and widely utilized system used to convert the solar energy for electric power applications. It can generate direct current (DC) electricity without any environmental impact and emission by way of solar radiation. The DC power is converted to AC power with an inverter, to power local loads or

fed back to the utility. Being a semiconductor device, the PV systems are suitable for most operation at a lower maintenance cost (RashmiSwami, 2012).

Photovoltaic cell is a generating unit of electricity that would be studied to increase the power output. The current amount generated by a solar cell depends on its efficiency, its size i.e. surface area and also the light intensity incident on the surface of the solar panel.

2.3 Light sensors

A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. The suns position is required to be monitored continuously. The presence of the solar panel is required to be sensed at the extreme ends. The light dependent resistors are used in the circuit to sense the change in the suns position. A photo resistor or light dependent resistor is a resistor whose resistance decreases with increasing incident light intensity. A photo resistor requires a power source enable it to generate a photocurrent, a photo effect in the LDRs is manifested by change in the materials electrical resistance. To utilize the photo resistor, it is placed in series with another resistor, thus forming a voltage divider at the junction between photo resistor and other resistor, the output is taken at the junction point to pass the measured voltage as input signal to the microcontroller.

Figure 1: Light dependent resistor

2.4 Servomotor

This is a type of motor that can rotate with great precision. Normally this type of motor consists of a control circuit which is able to provide feedback data on the current position of the motor shaft. It is made up of a single motor that runs through a servo mechanism. It consists of three parts;

1. Controlled device
2. Output sensor
3. Feedback system

All servomotors work directly with +5v power supply. They work on pulse width modulation principle meaning that its angle of rotation is controlled by duration of applied pulse to its control pin**Invalid source specified.**. The motor will rotate when the controller delivers an output, the corresponding pulse width modulation signals will drive the motor so as to adjust the position of the panel.

2.5 Microcontroller

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins of which 6 can be used as Pulse Width Modulation outputs, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller.

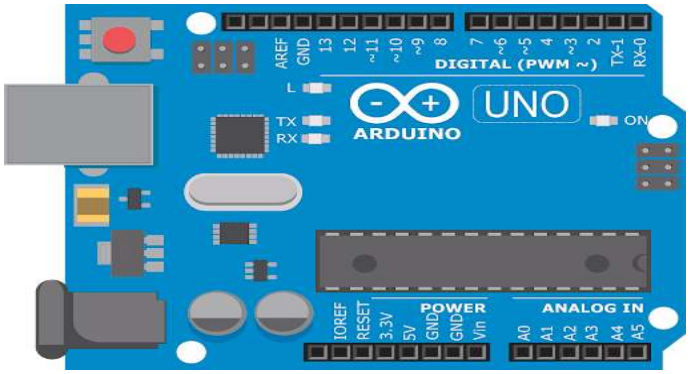

Figure 2: Arduino Uno

3. Methodology

The solar tracking system has done in three main phases.

- Research
- Coding and Design
- Implementation and Testing

3.1 Design components

Table 1: Components

COMPONENT	QUANTITY
Arduino Uno	1
Light dependent resistors	2
10k ohm resistors	2
Solar panel	1
3D printed; a) gears	1
b) Panel base holder	1
c) Panel base	1
Servo motor	1

For this project research covered on how to increase the efficiency of the solar photo voltaic cell and to know means and ways of increase the amount of power generated by the solar panels, this included;

3.2 Effect of the amount of solar incident to power collected

The amount of incident on a solar panel affects largely on the amount of power generated. The photovoltaic cells depend solar incident to yield energy this means that power generated by solar panel is high when it's perpendicularly aligned to the sun and the most possible way to do this is by the use of a tracking system.

According to Deepthi S in their research paper, a single axis tracking system is an ideology of continuously rotating the solar panel towards the sun's direction, by continuously tracking the position of the sun throughout the day. There are three types of single axis solar tracking systems:

1. Horizontal single axis tracking system
2. Vertical single axis tracking system
3. Tilted single axis tracking system

Horizontal single axis tracking- the rotating system is kept horizontal with respect to the ground, and the PV module is kept in parallel with the axis of rotation. In the vertical tracking system, the axis of rotation is kept vertical with respect to the ground and the PV module is kept at an angle with respect to the axis of rotation. In the Tilted solar tracking system, the axes of rotation are kept between horizontal and vertical axes and the PV module is kept parallel to the axis of rotation, similar to the Horizontal tracking system. The single axis tracking system consist of two light dependent resistors, both the light dependent resistors are placed on the panel base next to the solar panel and separated by a separator. Depending on the intensity variation of the sun rays falling on both the LDRs, the solar panel is rotated. As the day goes on, the intensity of light falling on the west side LDR increases and controller rotates the solar panel towards that side since it has high light intensity (Deepthi S).

S. Gupta, in their paper they explained that due to improved performance of the photovoltaic panels there is an increase in the design requirement of tracking system. Usually in mornings and evenings PV panels gets sun rays at an acute angle and in the case of a fixed solar panel the power output decreases continuously as the sun moves to the other side. Therefore to increase the amount of power produced means should be discovered to keep the PV panel aligned perpendicularly to the solar incident and solar tracking system is most commonly used for it (Gupta, 2016).

According to Ayushi Nitin Ingole in their paper they gave the importance of using solar energy and explained how electrical energy demand is increasing year by year due to globalization leading to the increase in demand of electricity and this has resulted to depletion of main resources available to provide energy, leaving natural resources as the only alternative to look into. The energy which is generated using this natural resources which are freely available in nature is called as renewable energy. Solar energy is the most suitable and convenient among all the renewable energy resources (Ingole, 2016). Because it is abundantly available in nature. Also, solar energy is environment friendly since it does not create any pollution unlike burning fossils to produce energy. Solar radiations from the sun is absorbed by the photovoltaic panels and converted into direct current electric energy. Kenya is advantaged by being on the equator thus having great potential of converting solar radiations to electrical energy.

3.3 Coding and Design

With the use of a computer a code which is the backbone for the tracking system was written, run and executed, this was made possible by using a computer-based software designed specifically for the microcontroller chosen for this project (Arduino Uno).

The first part of the code is expected to check the light intensity difference for the two Light Dependent Resistors, decode the information from the light dependent resistors, and lastly a relevant signal is sent to the motor.

With the code uploaded to the microcontroller it's expected that the microcontroller should calculate the analogue signal sent from the light dependent resistors and actively send an output signal to the servo motor that will rotate the solar panel to the desired direction of high light intensity

3.4 Implementation and Testing

The code was uploaded to the Arduino Uno microcontroller, the hardware parts used for implementing the circuit were assembled together with the software, and the system was tested to determine whether it meets the objectives.

3.4.1 Control unit

The microcontroller proposed in this system (Arduino Uno) is used to control all the activities of the solar tracker. The microcontroller receives data, analyzes it and gives an output. The output given is always dependent of or rather affected by the feedback signal the microcontroller receives from the servo motor.

3.4.2 3D printing

In the process of implementation we also used 3D printed material for the solar rotation gears, panel base and a panel base holder. This materials not only enhances the proper rotation of the solar panel but also they provide support to the solar panel. Below are the solar tracking system parts that were printed.

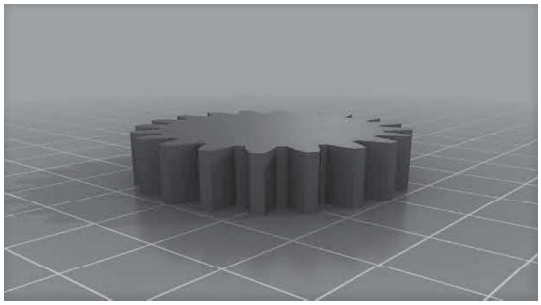

Figure 3: gear

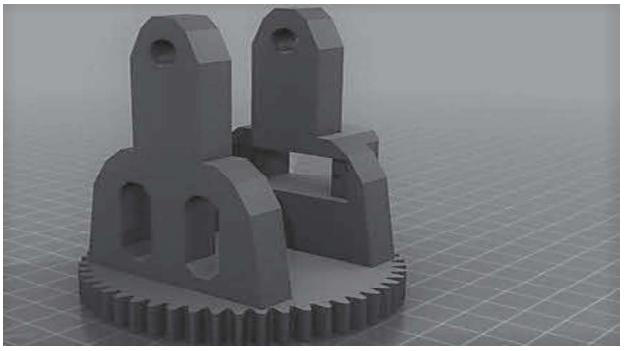

Figure 4: panel holder

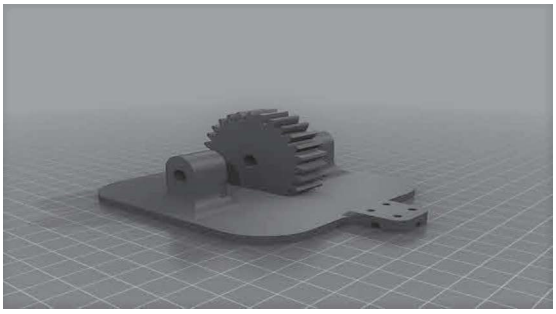

Figure 5: panel base

3.4.3 Pins connection

The connection for signal/data transfer to and from the arduino Uno microcontroller is as shown below.

Table 2: Connection

COMPONENT	CONNECTION TO MICROCONTROLLER
LDR 1	Pin A0
LDR 2	Pin A1
SERVO MOTOR	PWM pin 5

4. Results and Discussion

4.1 Tracking SYSTEM

After implementation of the solar tracking system the LDRs gives an output that is; reduced resistance on the side with high light intensity meaning a high amount of voltage to the arduino pin of that particular LDR and high resistance for the low intensity side LDR thus low voltage amount to the arduino.

$$Vout = Vin * \frac{R1}{R1 + R2}$$

The microcontroller analyses the signals and determines the direction with high light intensity then send a control signal to the servo motor to position the panel to the side with high light intensity, the output is always affected by the feedback signal from the motor this means if the panel is at position x and the signal to the servo motor is to rotate the panel to position x then the micro controller will receive the information and the output will not affect the position of the panel. When the panel is at apposition y the servo motor is going to rotate the panel to position x.

4.2 Analysis of the Power Produced

We were able to determine and compare the amount of power produced when using the solar tracking system and when not using it and the results were as shown below.

Table 3: Actual Data Collected

TIME	SINGLE SOLAR TRACKER MOUNTED PANEL			STATIONARY FIXED SOLAR PANEL		
	VOLTAGE(V)	CURRENT (mA)	VI(W) *10^-3	VOLTAGE(V)	CURRENT(mA)	VI(W) *10^-3
10:00AM	5.6	28	156.8	5.56	24.3	127.88
12.00 NOON	7.12	49	348.88	6.8	32	217.6
1:00 PM	6.8	35	238	6.4	28	179.2
2:30 PM	4.95	23.5	116.3	4.3	20.6	88.58
3:30 PM	7.2	57	410.4	6.6	41	270.6
4:30 PM	7.15	53	378.95	6.37	34	216.58
TOTAL			1649.33W			1100.44W

From the information we have in the table above we can calculate the percentage change and determine whether the use of the tracking system is going to help us increase the production of solar energy.

$$change\ in\ \% = \left(\frac{total\ tracking\ panel\ power - total\ fixed\ panel\ power}{total\ tracking\ panel\ power}\right) * 100\%$$

$= \frac{1649.33-1100.44}{1649.33} * 100\%$

$= 33.28\%$

It's evident from the above computations that there is an increase in percentage of the power produced by the use of a solar tracking system by 33.28% as compared to when the solar panels are mounted at a stationary position

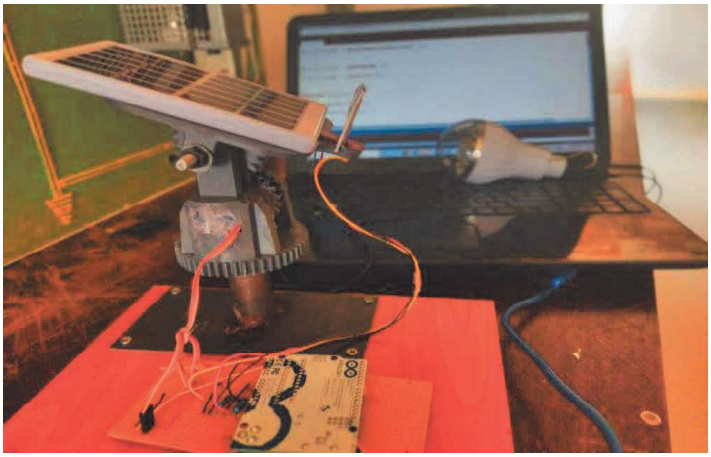

Figure 6: single axis solar tracker

5. Conclusion

The single axis solar tracking system has been successfully designed and implemented as explained, the system needs less initial cost to and increases the amount of power produced. Solar energy is gaining focus and priorities as the other conventional sources of energy are expensive and others are polluting the environment therefore on this journey of embracing the use green energy the use of solar tracking system is one of the best ways that should be used to increase the amount of energy produced by the solar panels, with is abilities to align the panels in perpendicular mode to the solar incident there is an increase in the amount of power produced as compared to when the solar panel is mounted at a fixed position. Based on the obtained results we can conclude that the proposed solution for a solar tracking system offers several advantages concerning the movement command of the PV panel; The solar tracking system also saves on space, when there is no enough space for installing many panels, solar tracking will be an effective method to generate more power with less panels in a limited space

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