

Development of Mechanical Solar Tracker Design

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Abstract

The research study investigated the prospect of coming up a design of a mechanical solar tracker, which would minimize human effort during operation. The affordable design would be compatible with different solar panel configurations for both domestic and industrial purposes. The mechanism would enable the panel to be placed at the best angle of exposure to sunlight for collection of energy as the sun moves across the sky throughout the day, as it incorporates the solar arrays to keep the array pointed towards the sun. It would have a provision for fitting solar panels to ensuring that the maximum amount of sunlight strikes the panels throughout the day. The system would be mounted on a pole 2.5 metres high, with a 2m by 1.5m panel to increase surface area for absorption of radiation. The set up is expected to generate about 20 - 25% more power when compared to a static solar model that are commercially available. It was established that installing the solar panels on a tracking base increases efficiency of the solar panels to 80%.

Keywords: *Solar tracker, design, solar panel, radiation, collection, sunlight, efficiency*

1. Introduction

Energy crisis is the most important issue in the world today (World Energy Council, 2016). Non polluting renewable energy resources are getting more attention as a way to lessen the dependency on conventional sources of energy. Solar energy is rapidly gaining the focus as an important means of expanding renewable energy uses, it is promising technology, being clean, silent, and reliable with very small maintenance costs and small ecological impacts. So, there is need to enhance the utilization of solar by increasing the efficiency of the solar cell to reduce the cost. It is in this regard that solar tracking system technology in taken on board to enhance the efficiency of the solar cells by tracking the sun throughout the day. There is great potential in solar energy harvesting from solar radiation as has been outlined so as to increase energy efficiency and also there is need for zero pollution energy production systems for the environmental friendliness.

2. Background

Most of the energy production is dependent on fossil fuels. The resources of the fossil fuels are limited and their use results in global warming due to emission of greenhouse gases. To provide a sustainable power production and safe world to the future generation, there is a growing demand for energy from renewable sources like solar, wind, geothermal and ocean tidal wave. The sun is the prime source of energy, directly or indirectly, which is also the fuel for most renewable systems. By 2015, 164 countries around the world had renewable energy support policies in support (International Energy Agency, 2016). Solar panel directly converts solar radiation into electrical energy. Solar panel is mainly made from semiconductor materials. Silicon used as the major component of solar panels, which is maximum 24.5% efficient. Unless high efficient solar panels are invented, the only way to enhance the performance of a solar panel is to increase the intensity of light falling on it. Solar trackers are the most appropriate and proven technology to increase the efficiency of solar panels through keeping the panels aligned with the sun's position. The point of maximum received energy is reached when the direction of the solar radiation is perpendicular on the panel surface thus an increase of the output energy of a photo-voltaic panel can be obtained by mounting the panel on a solar tracking device that follows the sun's trajectory. By using tracked solar arrays, a series of solar cells electrically connected, a DC voltage is generated more efficiently which can be physically used on a load. The power output of the solar panel is dependent on the amount of light that reaches the solar cell. Photovoltaic technology is most efficient when it is greeted by a light source at a perfectly perpendicular angle. In order to accomplish this, the PV panel must move with the sun to maintain this perpendicular angle. A solar tracking mechanism is an effort to increase the efficiency of power generation through the solar module. The conventional solar modules are stationary hence the sun rays falling

on them are at different angles at different points of time and the duration of the sun rays falling perpendicular to the surface of the solar module is very small thus large part of energy from sun is wasted.

3. Overview of solar tracking systems

A solar tracker could be defined as a device used to orient photovoltaic panels, reflectors, lenses or other optical device towards the sun. One way to make solar cells more efficient is by installing the solar panels on a tracking base that follows the sun position. A tracking system has some of these characteristics which entail one or two moving motors, light sensing device, continuous or stepwise movement, ability to track all year, and orientation adjustment with or without the tilt angle adjustment. Solar trackers can be divided into 3 types depending on the type of drive and sensing or positioning system that they incorporate. The major three types are passive, active and open loop trackers:

Passive trackers: These use the sun's radiation to heat gases that moves the tracker across the sky.

Active trackers: Use electric or hydraulic drives, and some type of gearing or actuator to move the tracker.

Open loop trackers: Use no sensing but instead determines the position of the sun through pre-recorded data for a particular site.

Trackers may be further classified as single or dual axis. Single axis trackers have one degree of freedom that acts as an axis of rotation. Solar trackers can either have a horizontal or a vertical axis. The horizontal type is used in tropical regions where the sun gets very high at noon, but the days are short. The vertical type is used in high latitudes where the sun does not get very high, but summer days can be very long. In concentrated solar power applications, single axis trackers are used with parabolic and linear mirror designs. In dual axis, solar trackers have both a horizontal and a vertical axis and, thus they can track the sun's apparent motion virtually anywhere in the world. Such systems may be operated under computer control according to the expected solar orientation, or may use a tracking sensor to control motor drives that orient the panels towards the sun. The two common types of solar trackers used are the servo-motor based and volatile liquid based:

Servo-motor based: In this system shown by Figure 1, panels move on a single path which is usually East-West direction, as during the day, the sun rises from East and sets in the West. The panel moves in accordance with the sun's movement and attempts to stay perpendicular to the angle of the sun's rays.



Figure 1 Servo based tracker

The tracker generates more electricity than its stationary counterpart, and it also returns to sunrise position for earlier start. This set up is more expensive and complex thereby requiring more maintenance effort.

Volatile liquid based: The volatile liquids in the metal canisters are heated at different rates due to the presence of the aluminium shadows. For the canister which is more exposed to the sun, the vapor pressure of its volatile liquid increases such that it escapes through the tube to the shadow area which is to the opposite canister. This causes a considerable difference in weight of the two canisters thus motion takes place in the direction with more weight and only stops if the canisters are equally exposed to the sun.

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Figure 2 Light-dependent resistors

The resistance of an LDR is very high, sometimes as high as 1 000 000 Ω , but when they are illuminated with light, the resistance drops dramatically. This effect of an LDR was the manipulated to initiate the motion of the motor. The stable position is when the two LDRs are having the same light intensity. When the light intensity source moves i.e. when the sun moves from west to east, the level of intensity falling on the two 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 the motor is used to rotate the solar panel in a way so as to track the light source.

A servomotor was incorporated as a rotary actuator or linear actuator to allow for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. The set up inside servo motor involves small DC motor, control circuit and potentiometer. The DC motor is attached to the control wheel via gears and as it rotates, the resistance of the potentiometer changes and the control circuit is able to accurately regulate the movement and its direction. The servo circuit is built inside the motor unit and comes with position able shaft that is fitted with a gear. The motor is controlled with an

electric signal that determines the amount of shaft movement in the assembly given in Figure 4 below, to minimize human effort in operating the solar tracker.

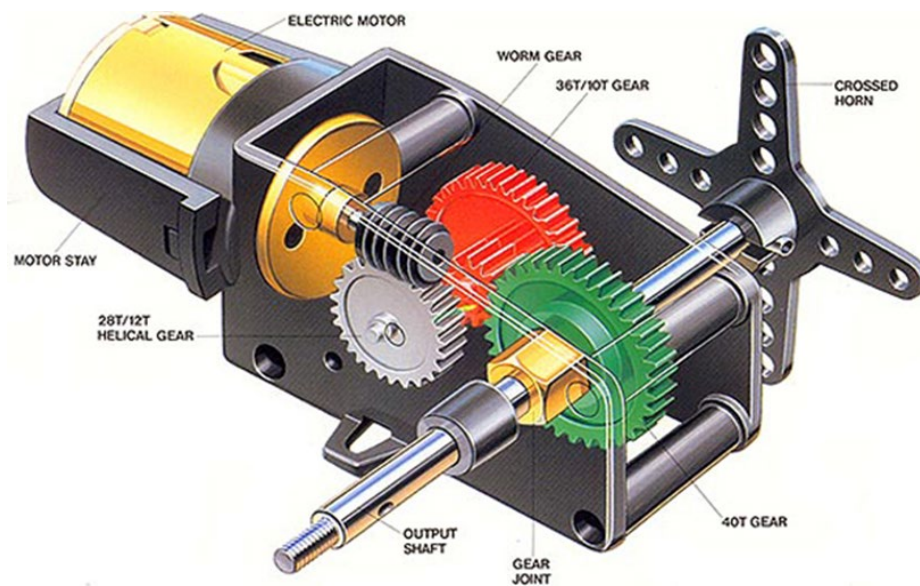


Figure 3 Servo-motor assembly

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 desired 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 set through electric pulses via signal wire. The speed of the motor is proportional to the difference between the actual position and the desired position. Therefore, if the motor is close to the desired position, it moves slowly. Otherwise it turns fast (Antonio L. Luque, 2007).

Microcontroller would need to be programmed to perform as required based on the program loaded in its main memory. The code is converted into binary form (zeros and ones) which are understood by the microcontroller. The programming language used makes use of English-like statement and is therefore closer to human language than it is to machine language which is the binary form. A 4 MHz crystal oscillator was used in conjunction with the PIC16F877 to provide the necessary clock input. Control Processing Unit (CPU) will constitute the microcontroller as the heart of the system since the project is software controlled. The microcontroller selected for this study would be able to convert the analogue photocell voltage into digital values and also provide four output channels to control motor unit. Software design was done using Arduino IDE (programming) using C language. Proteus circuit editing was used for drawing the PCB circuit. Design of circuit was done using Eagle Software. Figure 5 gives a simplified flow chart of assembly.

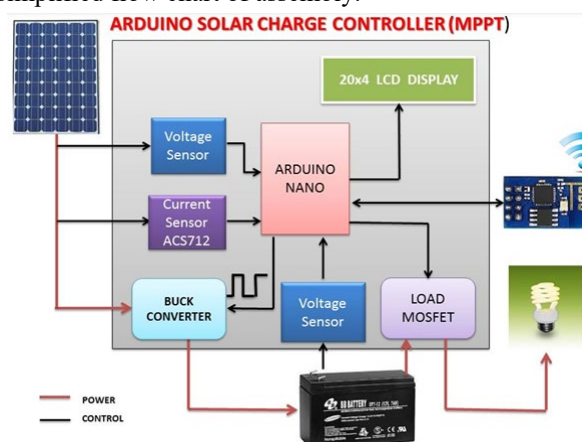


Figure 5 Flow Chart

The algorithm and code listing for motor control is generated by input of voltages from two LDRs which are analogue when converted to digital. When the two digital values are compared and the difference between them obtained, this gives the error proportional to the angle of rotation of the servo motor. If the LDR voltages are the same, the servo stops. Otherwise, the servo rotates until the difference is the same.

The design specifications

Solar panel specifications:

Type-Series: EN156P-60
Mass: 18kg
Power Range: 235 – 260Wp
Dimensions: 1636×986×35 mm

Specifications of the servo motor to be used:

Power rating: 900W
Speed: 250rpm

5. Recommendations and conclusion

Although a solar tracker was designed on a portable scale, it is economic if it is implemented on a much larger scale. For locations off or away from the equator dual axis trackers may be handy for capturing maximum solar radiation. It is recommended that in future, one may consider the use of more efficient sensors, which are cost effective and consume little power for this application. This would further enhance efficiency.

A solar panel that tracks the sun was designed and implemented. The required program that specified the various actions needed for the program to work was written. As a result, solar tracking was achieved. The system designed was a single tracker. While dual axis trackers are more efficient in tracking the sun, the additional circuitry and complexity was not required in this case. This is because Zimbabwe lies near the equator and therefore there are no significant changes in the apparent position of the sun during the various seasons. Dual axis trackers are more suitable in regions where there is a change in the position of the sun.

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Biography

Ignatio Madanhire graduated with a PhD in Engineering Management at the University of Johannesburg, South Africa, he is also a Senior Research Associate. He is also a lecturer with the Department of Mechanical Engineering at the University of Zimbabwe. He has research interests in engineering management and has published works on cleaner production in renowned journals.

Charles Mbohwa is a Professor of Sustainability Engineering and currently Vice Dean Postgraduate Studies, Research and Innovation with the University of Johannesburg, SA. He is a keen researcher with interest in logistics, supply chain management, life cycle assessment and sustainability, operations management, project management and engineering/manufacturing systems management. He is a professional member of Zimbabwe Institution of Engineers(ZIE) and a fellow of American Society of Mechanical Engineers(ASME).