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SOLAR TRACKING SYSTEM FOR AFRICA'S UNDERUTILIZED SOLAR POWER

Emmanuel Mensah Agbenu, Rose-Mary Owusuaa Mensah, Osman Yakubu, Paul Sarfo
Department of Computer Science/Information Technology, Garden City University College, Kenyasi, Ghana
mensahowusuaa@gmail.com;

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Abstract— Society is currently struggling with the near extinction of fossil fuel, a non-renewable source of energy supply, resulting in the overburdening of electrical grid systems. This has contributed towards environmental pollution and consequently global warming. For this reason, there is call for a reliable and environmentally friendly source of energy supply, typically known as the green energy. Many options are available such as the wind vans, hydropower and the solar panel power systems. However, solar panel stands above the rest with respect to reliability, efficiency and its positive impact on the environment. Our research aims to improve the efficiency of solar panels systems by implementing a tracker that automatically corrects the misalignment between solar panel and the sun by keeping the solar panel perpendicular to the sun. As more sunlight strikes the panel, a lot of light is absorbed and thus increasing the energy output tremendously. The solar tracker is based on a proposed light sensor algorithm which uses four light dependent resistors (LDRs) which have been positioned in a compartment close to the solar panel. All the LDRs are exposed to sunlight and the one with highest light intensity determines the direction in which servo motors rotate the solar panel. The proposed system resulted in the ability to track the sun on both axes, the daily and seasonal movement of the sun and ensures an increase in solar panel efficiency and electricity generated as compared to the existing systems.
Keywords— Arduino; Light dependent resistor; panel; solar; servos, tracker;

I. INTRODUCTION

Society depends heavily on energy for survival. The increase in technological products has been a keen problem since these products depend heavily on energy for their operation. Conventional energy resources are not environmentally friendly due to their contribution towards environmental pollution by burning of fossil fuel. The use of renewable source of energy is becoming popular, with so many technologies available which provides alternative source of energy supply. However, solar technology is rising above the others with its environmental friendliness, reliability and efficiency.

In the midst of the global energy crisis, African countries receive many hours of bright sunlight and heat during the year than any other continent hence considered the "Sun Continent" [1]. With this advantage, they can greatly benefit from solar plants to support its current overburdened electrical grid. Despite this advantage, power supply in Africa remains inadequate and there are repeated blackouts which negatively affects businesses in these areas [2]. Currently, cost of sophisticated solar technologies and economic factors makes solar power unrealistic for many Africans [2]. Therefore the aim of this paper is to build a solar tracker using simple homemade materials and basic electronic components at a small scale to increase the efficiency of the solar panels available on the continent.

II. LITERATURE REVIEW

The solar power works by capturing energy from the sun and converting it into electricity for home and industrial usage [3]. The International Energy Agency indicated that since 2010, solar photovoltaic capacity has increased considerably as compared to previous four decades [4]. Tsao et al. indicated that there is more energy from the sun that hits the earth in just an hour than worldwide consumption for the year 2010 [5]. This clearly shows the incredible potentials available in solar power. The solar power system consists of solar panels, solar battery storage system and solar invertor as displayed in fig 1 which works together to produce the energy needed.

Fig. 1. How solar panel system works [6]

The term "peak sun hours" refers to the insolation which a solar panel would receive if the sun were shinning at a maximum value for a certain hours of the day [7]. The amount of sunlight hitting any location varies from sunrise to sunset due to factors such as the clouds, the position of the sun in the sky and the atmosphere. The highest sunshine occurs at the noon which is the time when the sun is highest in the sky as compared to the rest of the day. Sunlight in the morning and evening does not give as much energy as at noon due to low angles. Aside daily variation in the sunlight output, there are seasonal differences as well. There is more sunlight in the summer than other seasons due to the position of the sun in the sky and almost clear sky hence an hour of sunshine delivers more energy as compared to the same hour of sunshine in other seasons [8]. Fig 2 below shows daily variation in insolation with respect to time of the day. It shows that the sun peaks at noon and hence generates more sunlight during this period. Energy consumption is directly proportional to a country's GDP [9] and therefore it is important for mankind to focus on ways in which solar power can be effectively harnessed. When utilized, solar power can also address climate change issues by serving as an alternative to fossil fuel [10].

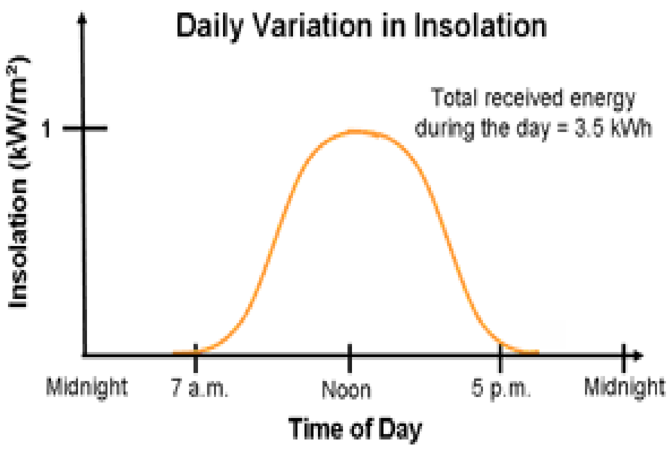

Fig. 2. Daily variations in the sun insulation [8]

III. CURRENT SOLAR PANEL SYSTEMS

Solar power system consisting of photovoltaic panel and solar battery is responsible for converting solar energy into electricity. There are different types of solar panel systems available; they are characterized by their moving mechanism

A. Stationary solar mount (rooftop solar panels)

The most popular solar system uses the stationary mount, which holds the panels in a fixed angle, mostly on rooftops as illustrated in Fig 3. This implementation may have a downside when the sun moves to a less than ideal angle, thereby affecting the productivity of the solar panel. For the solar power system to work effectively, it requires exposing the solar panels to direct sun rays. Often, there is lengthy period where the stationary panels cannot harvest energy from the sun and this leads to loss of energy. This problem has reduced the attractiveness of solar energy as a means of empowering businesses and homes across the African continent.

Fig. 3. Standard rooftop panel system

B. Manual solar tracker

To mitigate the shortcomings of the regular rooftop solar panels, some operators try to manually adjust the solar panels in order to align it with the sun as shown in Fig 4 below. This method requires time and careful deduction of the current sun's position. This approach requires constant tilting of the solar panels by the operator on site and hence may be highly inconvenient and the solar panels may still miss the best part of sunshine. However, this approach is still an improvement over the fixed rooftop approach and may produce more energy.

Fig. 4. Manual solar tracker with ropes which need to be manually tilted towards the direction of the sun

IV. PROPOSED SYSTEM

With the aim of achieving higher efficiency and making solar power cost effective in the long run, we propose a system that will intelligently track the position of the sun throughout its lifecycle. This can be achieved by using a reliable electronic component like the photo resistor (LDR) to determine the position of the sun and using an actuator (Servo Motor) to move the photovoltaic panels to the sun's current position. By using the LDRs and the Servo Motor, the solar tracker can be autonomous throughout its life span while sacrificing the frequent adjustment of the panels by the solar operators to achieve the desired energy output.

C. Flow chart of the proposed system

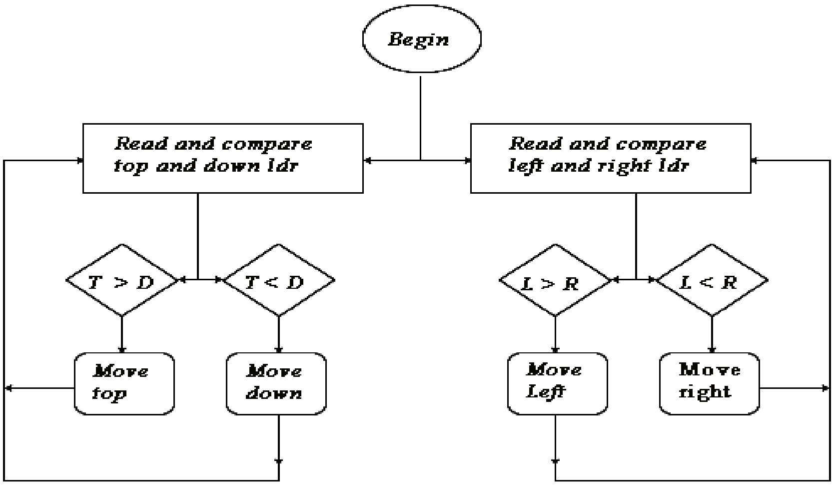

Fig. 5. Flow chart of the proposed algorithm for the solar tracker

The flow chart outlines the operation of the sun tracking algorithm implemented, which contains the initialization and operation module. The initialization module is where the LDRs and Servo Motors are declared and initialized. The operation module is an infinite loop which contains the main operation of the continuous sun tracking using the Light sensors and motors. The LDRs serve as input to the solar tracker by determining sunlight intensity. There are two comparisons made throughout the working hours (6:00 am – 6:00 pm) of the solar tracker, namely the top – down and left – right comparisons. The result of each comparison determines the direction in which the servo motors tilt the panel stand.

V. SYSTEM COMPONENTS

The components in Fig 6 were utilized during the design of the solar tracker.

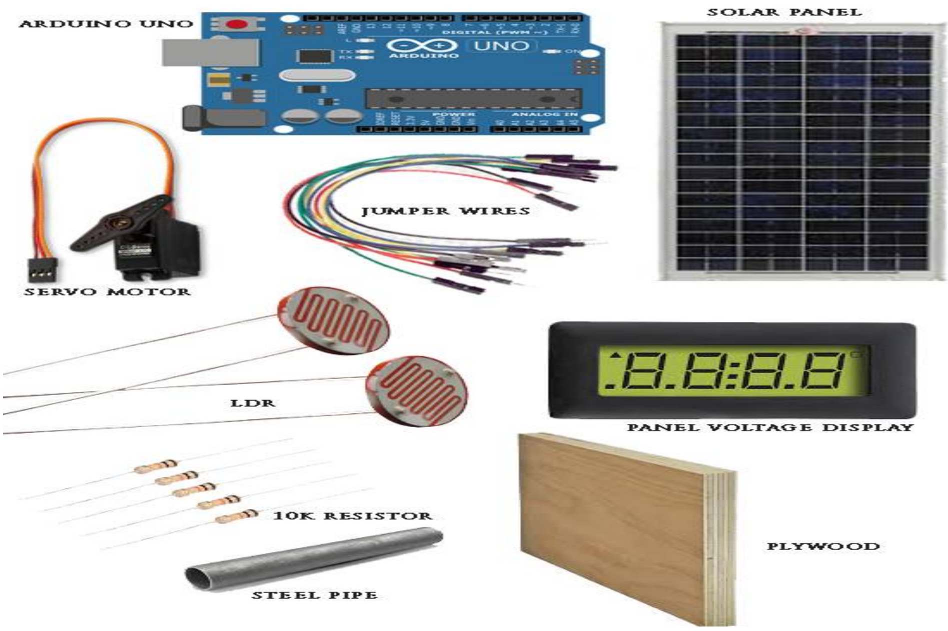

Fig. 6. The proposed system components

A. Arduino Uno microcontroller

The Arduino Uno microcontroller is part of the Arduino microcontrollers. It is based on the ATmega328. It consists of 20 digital input/ output pins, of which 6 can be used as PMW (Pulse Width Modulation) outputs and 6 for analogue inputs, 16 MHz resonator, a USB cable for power connection and reset button. It controls the other components of the system.

B. Servo motors

Servo motors are used to move other components connected to the microcontroller. It has 3 wires; GND, power and signal. Most often, the red wire is the power which is connected to the 5V pin of the Arduino. The GND is mostly black which is also connected to the any of the GND pin of the Arduino microcontroller. The signal wire is the yellow or orange wire; it is connected to any of the digital pins on the Arduino Uno. The servo motor draws considerable amount of power, for this reason, it is most reliable when powered by an external source. However, the Arduino Uno can supply the 5V needed by the motor. The servo motors are responsible for rotating the solar panels.

C. Light dependent resistors

A light dependent resistor is a component that has a resistance which varies with the light intensity shone upon it. For this reason, it is suitable for light sensing projects. LDRs are used to automatically turn on/off lights like the streetlights and also used to detect light source. Four LDRs are used in this proposed solar tracker to sense sunlight. The LDR is an analogue sensor hence they are connected to the analogue pins on the Arduino Uno microcontroller. They are connected with 10K resistor in a series. Each LDR is positioned in the mini four quadrant compartment attached to the solar tracker

VI. HARDWARE IMPLEMENTATION

The steps described below were undertaken in order to develop the solar tracker.

A. Building the base and the panel stand

A piece of plywood of dimensions 16cm x 10cm was used for the base. A plywood with the size a little larger than the panel used with a further 6cm x 5cm on one side of the plywood was used for the panel stand and the LDRs compartment. The 5cm x 5cm cut-out part of the top wood was divided into four part using a slight plywood with a height of 4cm to form a quadrant as shown in the figures below. A small hole (the size of a leg of an LDR) was drilled in the four parts of the LDR quadrant for each LDR.

B. Building the stand

A 16cm rectangular steel was used for the stand and another steel with the width equivalent to the width of the panel stand was screwed to the stand to form a T-shape as illustrated in Fig 7. Furthermore, two small piece of steel with the length of 4cm was attached to the top steel as shown in the figure below. Again, another steel was used to form a servo mount and screwed at two opposite side of the 16cm steel so that the servo will be firmly held inside.

Fig. 7. System design showing the stand, servo mount and top steel

C. Attached the two servos to the stand

The two servo motors were attached to the steel stand as displayed in Fig 8. The two brown wires of the two servo motors was connected together to form a single negative cable or the GND cable to minimize cable connections to the Arduino board.

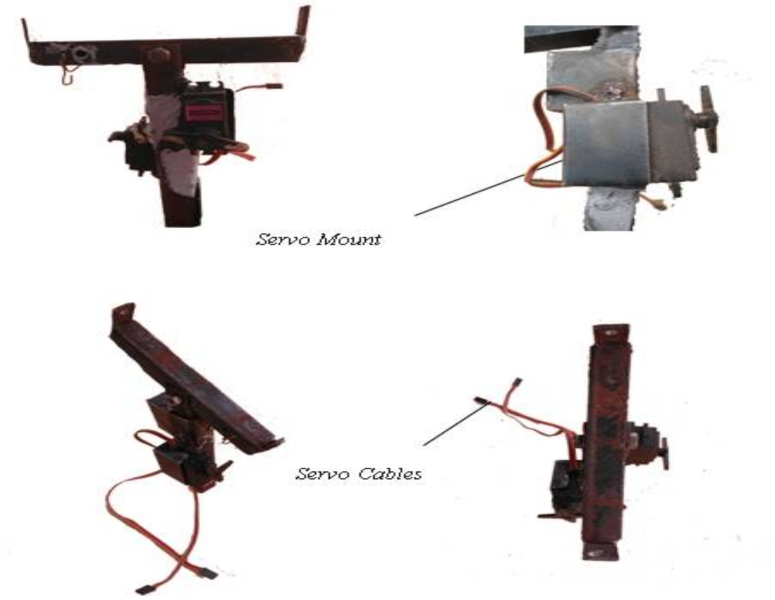

Fig. 8. Attaching servo motors to stand

D. Attaching the top wood to the base

The panel stand was screwed to the top steel at the middle side of the panel stand. This enabled the free up and down movement of the panel stand as shown in Fig 9 below

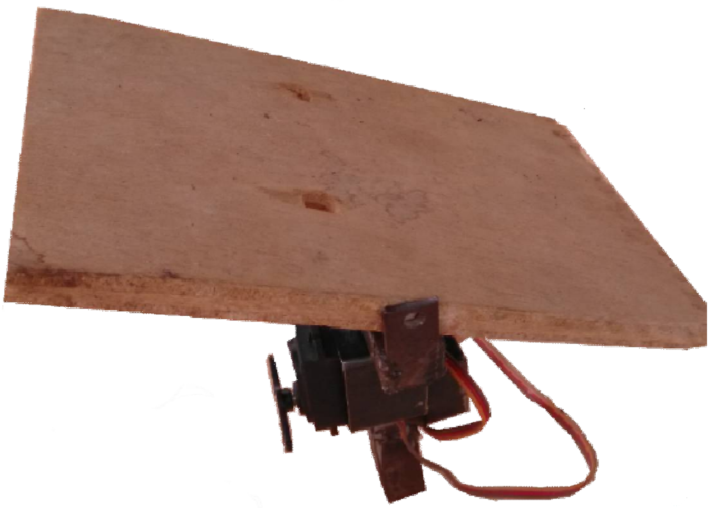

Fig. 9. Attaching the top wood of the steel base

E. Connecting the LDRs

An LDR was placed in each hole in the LDR compartment. One leg of each LDR was connected together and soldered to a jumper cable to serve as the power line for the LDRs. A 100k resistor was connected to each of the remaining legs of the LDRs and a jumper cable was connected to each LDR, where the leg and the 100k resistor were connected together. Finally, the other legs of the 100k resistors were connected together using a jumper cable to form the negative or the GND for the LDRs

F. Painting the LDR compartment black

The LDR was responsible for detecting sunlight and determined the movement of the solar panel. Therefore, it was important that the LDR gave accurate reading of sunlight and hence to ensure accurate reading of the LDR, the LDR compartment was painted black to enable correct alignment of the solar panel as illustrated in the Fig 10 below.

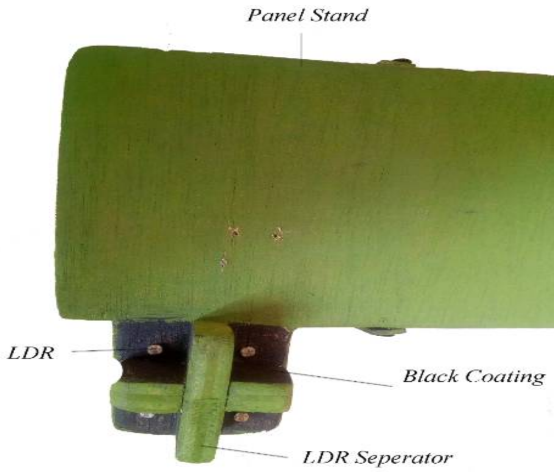

Fig. 10. Painted LDR quadrant

G. Attaching the Arduino

The Arduino Uno board was screwed to the base wood. The power cables of the servo motors and LDRs were connected together to form a single power cable to maximize the 5V of Arduino. Likewise, the GND cables from the two servo motors and the LDRs were connected to one of the three GND pins on the Arduino board. Similarly, the other legs of the LDRs were connected to A0-A3 of the analogue pins of the Arduino and the two signal of the servo motors were connected to digital pin 10 and 11 of the Arduino Uno. The final assemble and connections are shown in Fig 11 below.

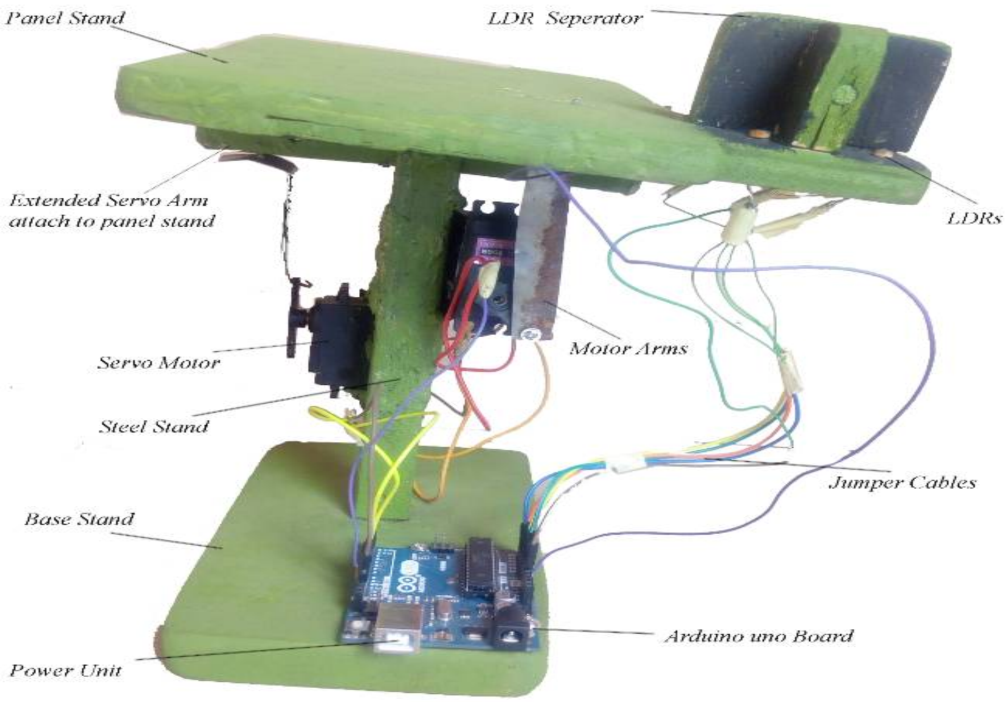

Fig. 11. Final assemble of the system showing all part of the system

VII. SOFTWARE IMPLEMENTATION

The software for this system was programmed in Arduino IDE. It is an open source integrated development environment which is used to develop IOT (Internet of Things) applications and other smart applications. It supports the development of microcontrollers using C++ and C language for its development. It is the most popular environment used for the IOT ecosystem. The software written with Arduino is called sketches. The sketch is uploaded to the Arduino Uno using USB cable from the computer which also serves as the power source for this system due to the size and power requirement of the system as displayed in Fig 12 below.

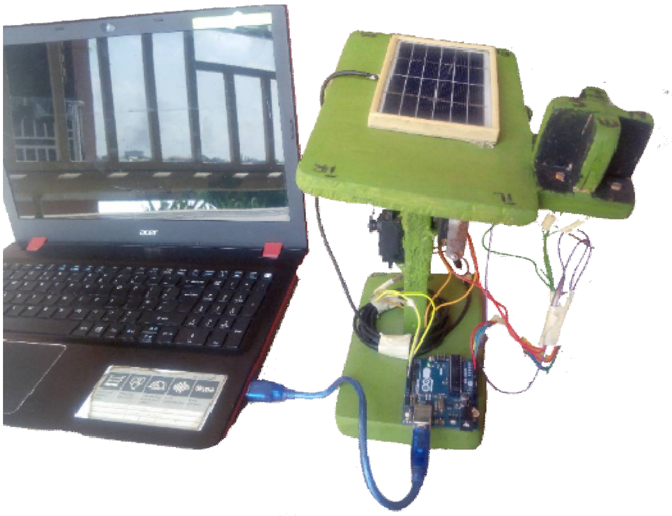

Fig 12. Connecting the system to a computer for power and software upload

VIII. RESULTS

At the end of implementation, the solar tracker shown in Fig 13 below was able to meet its specification. It was able to track the sun and align the solar panels with the sun. The whole system which is made up of basic electronic components was able to perform the following functions

- Tilt the solar panel in two different axes
- Precisely predict the position of the sun
- Accurately align the solar panel with the sun's current position
- Work throughout the sun's active hours

Fig. 13. Final system view of the system

During testing, the solar tracker was able to detect any source of light (a touch light from a Smartphone and sunlight) and correct the misalignment between the solar panel and the light source. The servo motors enabled a flexible rotation of the solar panel. This accounted for the higher performance of the solar tracker, which is an improvement of the manual tracking systems and the fixed roof top systems. Figure 14 shows the solar panel at different directions where the sunlight was highest.

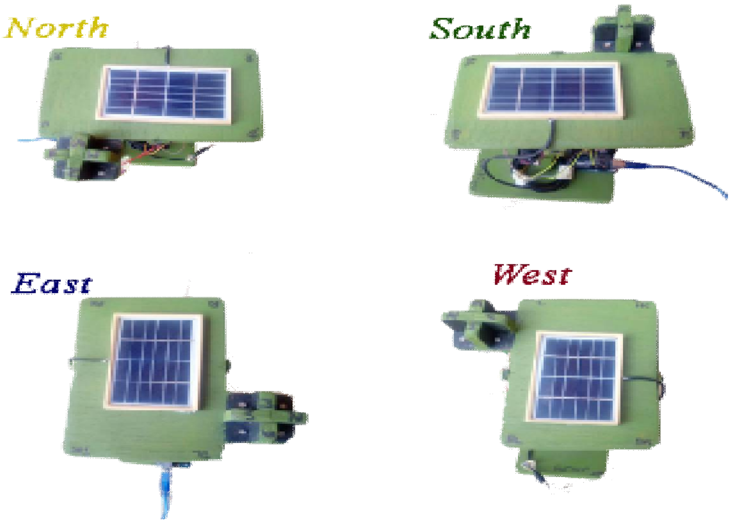

Fig. 14. Positioning of panel depending on sun's position

IX. CONCLUSION

The aim of our research was to address the problem of solar power inefficiency in African countries. To achieve this objective, we have designed and implemented an autonomous sun tracking system using basic electronic components to correct the misalignment between solar panels and the sun in order to derive more energy. This approach will reduce the cost of solar panel installations by reducing the number of panels required to generate maximum electricity. Overall, this research has led to a cost effective solution for solar installations especially in areas where sunlight abounds throughout the year as in the case of Ghana and other African countries.

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