Development of an Intelligent and Efficient Tracker System for Standalone Application using Arduino

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ABSTRACT

Energy from the sun is one of the most used renewable forms of energy as the alternative to the conventional energy source. So steps into the proper harvest of this naturally occurring energy become paramount. This work presents an intelligent Arduino processor tracking system which detects the solar angle of incidence using Light Dependent Resistors (LDR). This LDR is a light sensor interfaced to Arduino processor. This is programmed to detect the sunlight through the LDRs and then actuate the stepper motor to position the solar panel where it can receive maximum sunlight. Dual axis solar tracker extracts maximum solar energy levels due to its ability to align to the sun vertically and horizontally.

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***Keywords**: photovoltaic, solar tracking, Arduino processor, stepper motor, light dependent resistor.*

1. Introduction

Recently, due to epileptic power source experiencing by many people, a quest for the renewable energy source is now a priority. There are several types of renewable energy sources that are currently being studied and implemented into a multitude settings, these include wind, hydro-electric, and solar energy, among others. While the two former sources are mostly built on a large scale, the latter, solar energy systems can be built in both small and large scale and still provide economic benefits. Solar energy is a field that is on the rise and will likely become integrated into more and more aspects of our life. Solar energy is of great interest to many groups and individuals around the globe but it is very important to sun-rich areas like Nigeria and other northern Africa countries.

Solar energy has been in the existence for a couple of decades now, but analysis has shown that there is great energy lost in solar harvest especially in early morning and late afternoon. This means fixed solar panels don’t capture much solar irradiation within this period. In view of this, the dual axis solar tracking system was designed. The sun

travels through 360 degrees east-west a day, but from the perspective of any fixed location, the visible portion is 180 degrees during a ½ day period.
Local horizon effects reduce this somewhat, making the effective motion about 150 degrees [1]. A solar panel in a fixed orientation between the dawn and sunset extremes will see a motion of 75 degrees on either side and thus, will lose 75% of the energy in the morning and evening [1].

The sun also moves through 46 degrees north-south over a year. The same panels set at the midpoint between the two local extremes will thus see the sun move 23 degrees on either side, causing losses of 8.3% [1]. A tracker such as this dual axis could account for both the daily and seasonal motions. The control system required is much more complex and sophisticated than that of a single axis system, however, the resultant increase in energy efficiency compensates for it. Tracking systems improve performance for two main reasons. First, when a solar panel is perpendicular to the sunlight, it receives more light on its surface than if it were angled. For large systems, the energy gained by using tracking systems can outweigh the added complexity trackers can increase efficiency by 30% or more [1]. To maintain accuracy and flexibility in design, the use of Arduino processors is very pertinent. The dual axis tracking system is an independent system that could serve as standalone or grid connected.

2. Related Work

Electricity is essential to every society and economy in our world. With growing populations and expanding economies the need for electricity is increasing worldwide. Unfortunately, much of the world's electricity generation depends on burning of fossil fuels. In the 20th century, the use of fossil fuels increased by ten times. Fossils fuels now provide about 90% of the world's commercial energy needs. Much of the world's transportation also depends on fossil fuels. These uses of fossil fuels have helped increase the worldwide emission of greenhouse gases. There is a shift taking place around the world to reduce greenhouse gas emissions in the production of electricity. Some power companies and governments are beginning to introduce renewable energy sources to replace fossil fuels in the production of electricity. Electricity generated by photovoltaic (PV) systems is one of these renewable energies and it does not produce greenhouse gases. In addition to this, oil and gas reserves that are easy to access are becoming hard to find. As these fuels become more expensive, other kinds of fuels will become increasingly important. Because solar energy is clean, safe and renewable, it is being used more than ever before. As more research into PV technology is done, new kinds of PV systems and PV tracking are being introduced. The integration of trackers and sensors into PV technology optimizes the performance and makes the system to be viable. Work done by [2] gave process architectures for tracking fusion. The concept of multiple targets tracking PV was used because tracking with multiple sensors provides better performance than using a

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single sensor. One approach to multiple targets tracking with multiple sensors was to first perform single sensor tracking and then fuse the tracks from the different sensors. Two processing architectures for track fusion were presented: sensor to sensor track fusion and sensor to system track fusion. Different approaches for fusing track state estimates were presented, and their performance validated through theoretical analysis and simulations. In [3] a potential system was found, this used a stepper motor and light sensor to develop a system that tracks the sun to keep the panel at a right angle to its array. A solar tracker is designed employing the new principle of using small solar cells to function as self- adjusting light sensors, providing a variable indication of their relative angle to the sun by detecting their voltage output. Another by [4] investigates a high precision digital tracking system which adopts the coordinate calculation algorithm and photosensitive sensors. This system was designed to satisfy the precision requirement in sun tracking for a concentrated sunlight transmitting system via optical fibers. In [5], digital tracking system was developed to maximize the efficiency of a system and online orientation system was used to updates the PV panel position according to the instantaneous solar irradiation. A similar work by [6], was carried out to investigate the effect of using different types of sun-tracking mechanisms on the flat plate photovoltaic system performances and the main parameters affecting the amount of their output electrical energy as well as those affecting their gains compared to the traditional fixed photovoltaic systems. The evaluation of different systems was performed on the basis of analysis and simulation results. The performances of a PV panel mounted on fixed structures which were inclined according to a yearly and seasonal optimum, those fixed on a single axis sun tracking systems in a vertical manner and those with an inclined rotating axis mounted on a two-axis sun tracker mechanisms were considered and analyzed accordingly. In [7], a method was developed for sun tracking system using solar position algorithm. The simulation was carried out and simulation result was used to evaluate source codes with local parameters entered in a program. The simulation result was used to estimate zenith and azimuth angle of the sun over a period. Also [8] has presented the application of Solar Position Algorithm (SPA) to estimate the position of the sun in terms of zenith angle and azimuth angle. This algorithm can be utilized for the photovoltaic panels distributed remotely and controlled independently by a single computer. Work done by [9] gave the design and implementation of a fuzzy logic computer controlled sun tracking system to enhance the power output of photovoltaic panels. The tracking system was driven by two permanent magnet DC motors to provide motion of the PV panels in two axes. A computer-based (PC) fuzzy logic control algorithm utilizing the knowledge of the system behaviour was designed in order to achieve the control objectives of the system. In another work by [10], which involve the development of a low power consuming solar tracking cell for white Light Emitting Diodes (LED). In that system, the use of dc power generated by the fixed solar cells module to energize white LED light sources was studied. The operation is by direct connection of the white LED with current limiting resistors, resulting in much more power consumption. The use of white LED was presented as a general lighting application powered by tracking solar cells module and used pulse to apply the electrical power to the white LED.

3. System Design

The system design consists of several subunits as shown in the block diagram of figure 1 below. As could be seen in the architectural diagram below, the source voltage is a pure DC from the solar panel which is fed into the controller that continuously monitors the voltage that enters to the processor unit. The processor senses sun's angle through the LDR and in turns actuates the stepper motor as shown in the diagram of figure 1. As long as the sun shines the LDR signals the processor for either horizontal or vertical alignment positioning.

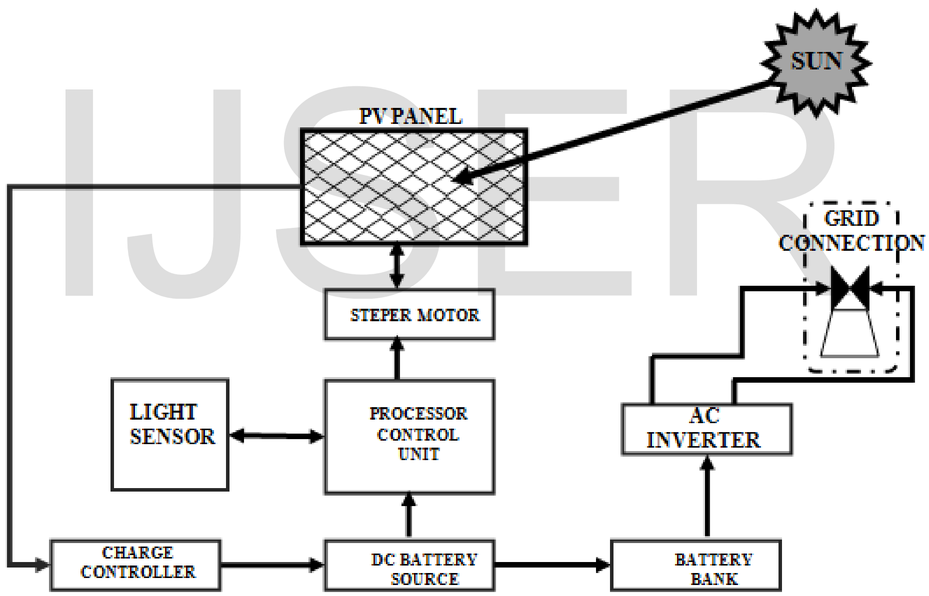

Figure1: System architecture.

3.1 Power Supply

The power source to the system consists of the solar panels and charge controller which regulate the voltage that enters into the Arduino processor chip. This is because; this work tries to develop a reliable system that uses renewable energy as its voltage sources and is independent of external voltage. However, in the design, a five watts solar panel was used to power the system.

3.2 Solar Panel Specifications

The solar Output Power (peak) is 5W Max Power Voltage (Vmp) and 17.6A as Max Power Current (Imp). It has 0.278V as the Open Circuit Voltage (Voc), 21.6A Short

Circuit Current (I_{SC}), and Working Temperature range of 228K to 358K Tolerance is ± 5% with a dimension of 265mm by 220mm by 18mm.

3.3 Design of Arduino Processor Control Unit

The Arduino Uno is a dedicated processor in the series of ATmega328 microcontroller system base. It has 14 digital input/output pins 6 can be used as PWM outputs, 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It has other additional functionalities of microcontroller system like 32 KB of flash memory for storing the code of which 0.5 KB is used for the bootloader. It has also 2 KB of SRAM and 1 KB of EEPROM which can be read and written with the EEPROM library [11]. The processor operates at 5volts and the 14 pins can be used as either input or output using pin model, digital write, and digital read functions. Figure 2 below is the Arduino processor with its pot arrangement. The Arduino has other circuitry and component integrated on the chip.

Figure 2: Arduino processor system showing input/output pins.

3.3.1 Programming the Arduino Chip

Arduino is one of the programmable integrated circuit (PIC) that works with the clearly specified algorithm. The Arduino chip has Integrated Development Environment (IDE) and this is where the Arduino code is written and compiled. The Arduino IDE runs on Java programming platform and very user-friendly. The Arduino IDE is easy to use and is open source it has an interactive online Arduino community that offers tutorials, resources and helps thereby making it easy for someone who has no programming experience to use the Arduino IDE. Figure 3 shows the programming environment where Arduino IDE was carried. Just like most of the embedded system Arduino was programmed and assigned responsibilities according to the algorithm in the flow chart of figure 4.

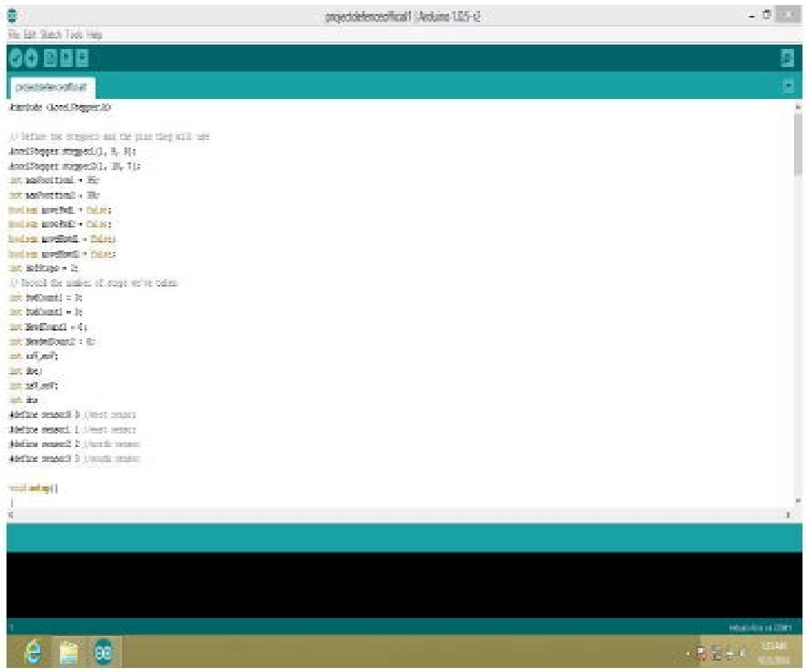

Figure 3: Arduino Integrated Development Environment (IDE).

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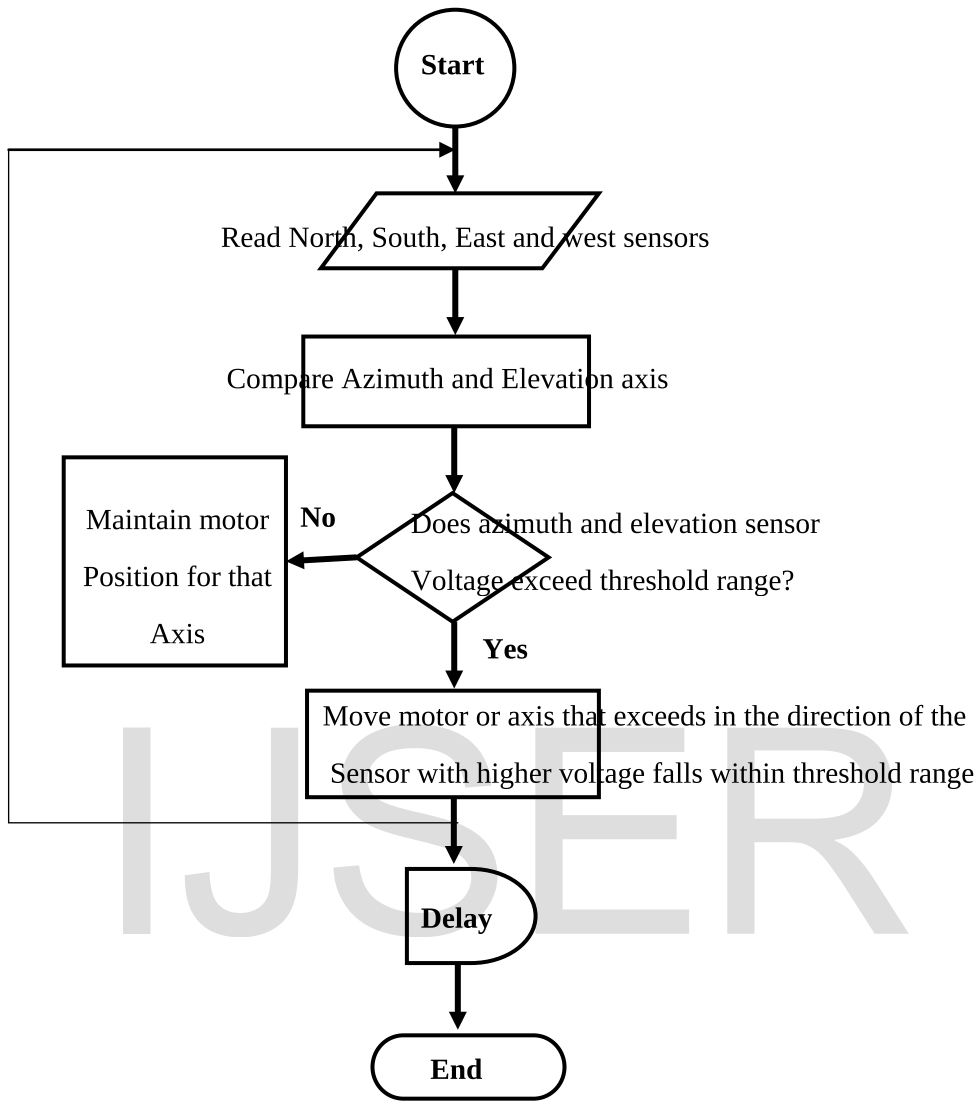

Figure 4: Program flow chart

3.4 Stepper Motor Control Unit

A stepper is a brushless dc motor whose rotor rotates in discrete angular increments when its stator windings are energized in a programmed manner. Rotation occurs because of magnetic interaction between rotor poles and poles of the sequentially energized stator windings. The rotor has no electrical windings but has salient or magnetized poles. In order words, a stepper motor is a digital actuator whose input is in the form of programmed energization of the stator windings and whose output is in the form of discrete angular rotation. However, the unique torque characteristics of stepper motor make it ideal for position applications. In fact, stepper motors have been used for years in applications such as printers and machining equipment. This type of motor will hold its position firmly at a

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given step providing a relatively high holding torque. Figure 3 shows the stepper motor used in the design with its specifications. The motors step Angle is 0.9/Step, Steps per revolution is 400, Voltage is 3.06, Current is 1.7A/phase, Holding Torque is 48 N.cm.

3.4.1 Stepper Motor Driver Unit

The Easy Driver is a simple stepper motor driver board it works like Allegro A3967 driver chip. It is compatible with anything that can output a digital 0 to 5V pulse. The easy driver requires a 7V to 20V supply to power the motor and can power any voltage of stepper motor. This means it has a true H-bridge design internally and sends current both ways through each of the two coils. You can use 4-wire, 6-wire or 8-wire stepper motors. The only kind it can't be used for is 5-wire stepper motors (They need unipolar drivers). It also has an inbuilt translator which simplifies the coding for the motor control.

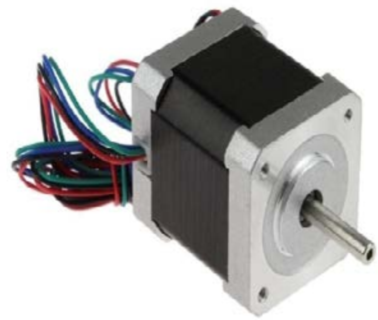

Figure 5: Stepper motor.

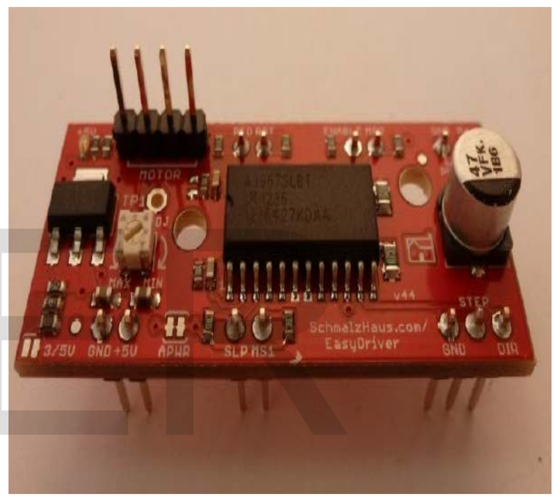

Figure 6: Stepper motor drive

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3.5 Analysis of Sensor Unit

This is a Photoconductive light sensor and does not produce electricity but simply changes its physical properties when subjected to light energy. The Light Dependent Resistor changes its electrical resistance in response to changes in the light intensity. Photo resistors are semiconductor devices that use light energy to control the flow of electrons, and hence the current flowing through them. The commonly used photoconductive cell is called the Light Dependent Resistor as shown in figure 4. As its name implies, the Light Dependent Resistor (LDR) is made from a piece of exposed semiconductor material such as cadmium sulphide that changes its electrical resistance from several thousand Ohms in the dark to only a few hundred Ohms when light rays fall on it by creating hole-electron pairs in the material [19]. The net effect is an improvement in its conductivity with a decrease in resistance for an increase in illumination. Also, photoresistive cells have a long response time requiring many seconds to respond to a change in the light intensity. The unit in figure 4 below has

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shown the diagram of typical Light Dependent Resistor.

Figure 4: Light dependent resistor.

3.6 The Tracker Mount Subsystem

This basically describes the components on which the solar tracking system is mounted. Several components are brought together to form two linear actuation systems i.e. one for each axis of rotation. These linear actuation systems are attached to the solar module. These linear actuation systems are described as stepper linear actuators and they convert rotational motion of the stepper motor into translational motion. Based on our system design, each 360-degree revolution of the stepper motor brings about a 1.2milimetre translational motion and this translational motion brings about the corresponding azimuth or elevation angle movement. In this design, pin load was considered because of the weight of the panel to affect the moment of inertia. The bearing makes it easier to move. The components used in designing the tracker mount system include;

- Stepper motors
- Nylon sleeve bearing
- Spacers
- Mild steel smooth rod
- Coupling

4.0 Implementation

The construction was done on a breadboard. This board is a versatile electronic prototype for designing and arrangement of the electronic component. It is of rectangular shapes with tiny holes for gripping of electronic component legs and pins. The circuit diagram of figure 5 below has the processor, stepper motor, and motor drive.

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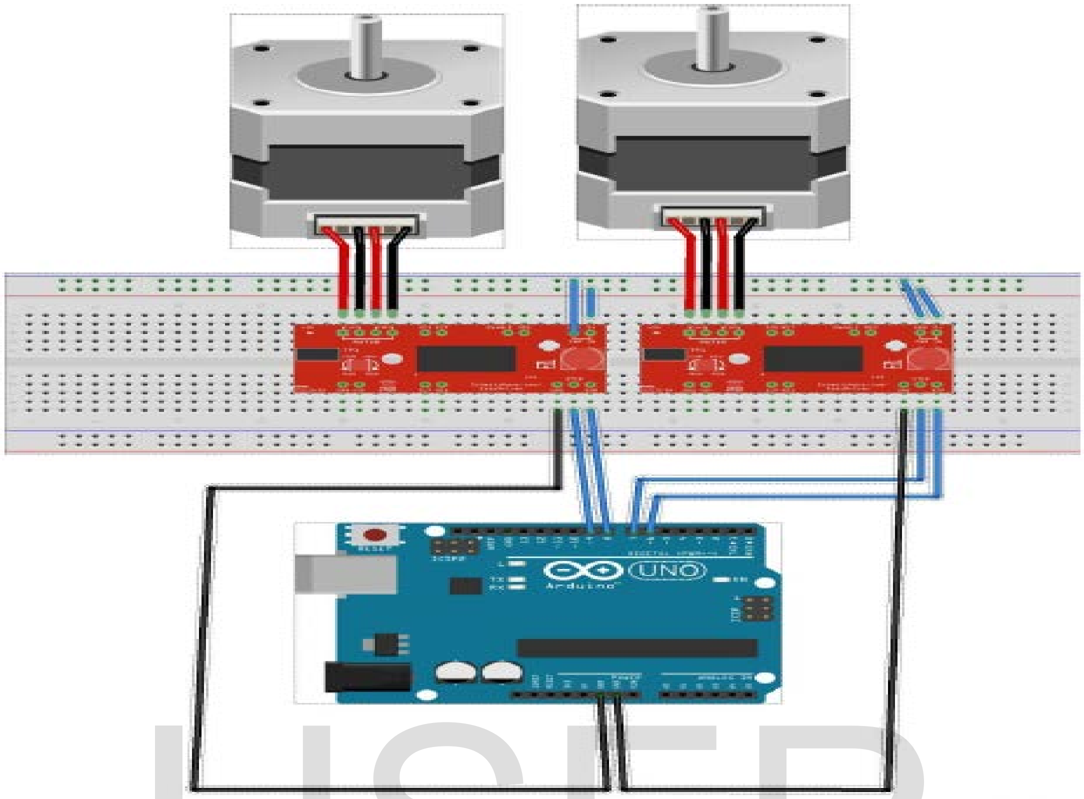

Figure 6: The components implementation showing motor, motor drive and Arduino processor

6. Conclusions

This paper was proposed to increase the efficiency of photovoltaic systems by tracking the sun and aligning the panel vertically to the sun. The energy wastage of photovoltaic modules due to shading and change in azimuth or elevation angles of the sun was addressed. This problem was solved by designing a system that ensures that the surface of the photovoltaic module is perpendicular to the angle of incidence of the sun at all times regardless of the change in the azimuth or elevation angle at any point on the surface of the earth. The movement of the tracker mount is effected by the presence of two stepper linear actuators which convert rotational motion into translational motion thereby bringing about the corresponding azimuth or elevation angle movement.

REFERENCES

[1] IEEE paper-:Model Based Design Controller for the Stepper Moto CalinRusu ,IulianBirou,

[2] Enikö Szoke Technical University of Cluj, Dept. of Electrical Drives and Robots

[3] *H. S. Rauschenbach*. Solar cell array design handbook. Van Nostrand Reinhold, 1980.

[4] *S. W. Angrist*, , Direct Energy Conversion, Allyn and Bacon, Inc., 4th edition, 1982, pp. 177-227.

[5] O. Wasynczuk, “Dynamic behavior of a class of photovoltaic power systems,” *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-102, no. 9, 1983, pp. 3031-3037

[6] Hasan. Mohammed et al, photovoltaic system modeling with fuzzy logic based maximum power point.

[7] J. Rizk, *and Y Chaiko*, solar tracking system: more efficient use of solar panels world Academy of Science, Engineering and Technology.

[8] Asmarashid Ponnira, Ammar Hashim, Artiffuddin Joret, A design of low power single axis solar tracking regardless of motor speed. International Journal of Integrated Engineering Vol.3

[9] Zainal Salam et al Application of Soft Computing Method for MPPT of PV System.

[10] Jifeng Song Youngping Yang Zhu, Zhou Jin, A high Precision Tracking System based on a hybrid strategy designed for concentrated sunlight concentration sunlight transmission via fibres Renewable Energy

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