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Development and Implementation of a Dual Axes Solar Tracking Charging System

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ABSTRACT: The poor state of the energy situation in Nigeria has been impacting very negatively on the life of the people, paralyzing industrial and manifesting machinery and stultifying economic growth of country. The paper overviews the development and implementation and drive system techniques that cover application of solar panel, the solar tracking system can be classified into two categories namely are classification based on nature of motion and classification based on freedom of motion. The paper described the various designed components of the tracking systems. However, the proposed average voltage with tracking system outperformed the average voltage without tacking of both in photovoltaic and LDRs output. The average voltage without tracking system is 9.27V and average voltage with tracking system is 12V. The average voltage with tracking system outperformed the average voltage without tracking system by 2.73V. This show that the average voltage with tracking system achieved better result than the voltage without tracking system, finally the percentage increase is 22.7%.

KEYWORDS: Solar tracker, Classification of solar tracking system, Photovoltaic effect, Azimuth microcontroller, Application of Solar panel.

I. INTRODUCTION

Solar energy is a very useful form of clean energy. In sunny areas of the world, solar energy is collected by solar panel and concentrated on water to produce steam to drive turbine and for domestic heating purposes. It can also be converted to electricity for lighting our home and streets. Solar energy is the energy available from the sun. The sun is the ultimate energy resources available from to man. Its energy does not deplete. It cannot be used up. Solar energy is used by green plants in the converted to electrical energy using photo cells. Solar radiation can be converted to chemical energy by photo chemical process. Solar energy can be used for heating homes and boiling water. This situation compelled the research community to pay attention toward renewable energy system. One of the great challenges for society is the provision of sufficient pollution free energy resources for future. Research in the field of renewable energy can solve this problem. Energy generated from renewable energy resources are those that can be replaced as they are used up. They can be continually replenished as they are exploited and utilized such as solar energy, wind energy, water energy, biomass, Tidal power, biofuel. Photovoltaic energy is one of the mature technologies amongst all renewable sources. To harvest solar energy, solar tracker is used which keeps panel perpendicular to the suns radiation in sunrise hours therefore, more energy could be collected. This paper also discusses the implementation of tracking system in PV power plants and its effectiveness on the final gain.

To tackle the problem of solar energy, the environmental impact needs to be addressed. Solar energy has a great effect on the environment, polluting the entire area and beyond. Burning fossil fuel for electricity generation also releases trace metals such as chromium, beryllium. Cadmium etc. Solar tracker system is used to track the sun's movement across the sky when tries to maintain the solar panel, panels can follow the path of the sun rays to ensuring that the maximum amount of sunlight is incident on the panel and produce more renewable energy throughout the day.

The main aim of this work is to position a solar panel that will be able to track the motion of the sun at any angle so that it can produce maximum power.

The objectives of this work are:

1. To build a device that when sun is high up in the sky, the tracking system must follow its position.
2. Using sensors as an active control to achieve its purpose of tracking
3. The system needs to be automatic thus making it simple and easy to use. The operator interference needs to be negligible and must be restricted.

Moreover, a solar tracker is a device that follows the sun as it moves across the sky. When solar trackers are coupled with solar panels, the panels can follow the path of the sun and produce more renewable energy for you to use.

Solar tracking systems allow solar panels to follow the sun path as it moves from east to west. They improve solar panels exposure to sunlight and increase the amount of energy they produce by ensuring they face for as much time as possible. Without trackers, installers have to choose a single orientation to maximize the amount of sun solar panels can get with solar trackers, a single panel can, for several extra hours a day, achieve the kind of efficiency that a fixed tilt panel can only get at its peak. We have used the concept of using the device which could sense the presence of sun and move the panel in that particular direction and not the concept of time to track the sun.

II. REVIEW OF RELATED LITERATURE

Long before the first Earth Day was celebrated on April 22, 1970, generating awareness about the environment and support for environmental protection; scientists were making the first discoveries in solar energy. It all began with Edmond Becquerel, a young physicist working in France, who in 1839 observed and discovered the photovoltaic effect— a process that produces a voltage or electric current when exposed to light or radiant energy. A few decades later, French mathematician Augustin Mouchot was inspired by the physicist's work. He began registering patents for solar-powered engines in the 1860s. From France to the U.S., inventors were inspired by the patents of the mathematician and filed for patents on solar-powered devices as early as 1888. Take a *light* step back to 1883 when New York inventor Charles Fritts created the first solar cell by coating selenium with a thin layer of gold. Fritts reported that the selenium module produced a current "that is continuous, constant, and of considerable force." This cell achieved an energy conversion rate of 1 to 2 percent. Most modern solar cells work at an efficiency of 15 to 20 percent. So, Fritts created what was a low impact solar cell, but still, it was the beginning of photovoltaic solar panel innovation in America. Named after Italian physicist, chemist and pioneer of electricity and power, Alessandro Volta, photovoltaic is the more technical term for turning light energy into electricity, and used interchangeably with the term photoelectric. Only a few years later in 1888, inventor Edward Weston received two patents for solar cells – U.S. Patent 389,124 and U.S. Patent 389,425. For both patents, Weston proposed, "to transform radiant energy derived from the sun into electrical energy, or through electrical energy into mechanical energy." Light energy is focused via a lens (f) onto the solar cell (a), "a thermopile (an electronic device that converts thermal energy into electrical energy) composed of bars of dissimilar metals." The light heats up the solar cell and causes electrons to be released and current to flow. In this instance, light creates heat, which creates electricity; this is the exact reverse of the way an incandescent light bulb works, converting electricity to heat that then generates light.

CONCEPT OF SOLAR PANEL

Solar panels are those devices which are used to absorb the sun's rays and convert them into electricity or heat.

A solar panel is actually a collection of solar (or photovoltaic) cells, which can be used to generate electricity through photovoltaic effect. These cells are arranged in a grid-like pattern on the surface of solar panels.

Thus, it may also be described as a set of photovoltaic modules, mounted on a structure supporting it. A photovoltaic (PV) module is a packaged and connected assembly of 6×10 solar cells.

CONCEPT OF SOLAR TRACKING SYSTEM

Solar tracker, a system that positions an object at an angle relative to the Sun. The most-common applications for solar trackers are positioning photovoltaic (PV) panels (solar panels) so that they remain perpendicular to the Sun's rays and positioning space telescopes so that they can determine the Sun's direction. PV solar trackers adjust the direction that a solar panel is facing according to the position of the Sun in the sky. By keeping the panel perpendicular to the Sun, more sunlight strikes the solar panel, less light is reflected, and more energy is absorbed. That energy can be converted into power.

There are two main solar tracking systems types that depending on their movement degrees of freedoms are **single axis solar tracking system and dual axis solar tracking system**, which are addressed in the recent studies. Furthermore the dual axis solar tracking system is the case study of this paper.

Classification of Solar Tracking System

Solar tracking system can be classed into two categories namely:

Classification Based on Nature of Motion

This is further divided into passive and active solar tracking systems:

A. Passive (Mechanical/Chemical) Solar Tracking System: This system uses the idea of thermal expansion of materials or a low boiling point compressed gas fluid driven to one side or the other as a method for tracking. Typically chlorofluorocarbon (CFC) oar type of shape memory alloy is place done it her side of the solar panel. When the panel follows the path of the sun with the sun and produces more renewable energy for you to use. Once the sun moves, one side is heated and causes one side to expand and the other to contract, causing the solar panel to rotate. A passive systemhasthepotentialtoincreaseefficiencyby23%. These systems are cheaper than active systems, but are not commercially popular. And also, these have viscous dampers that prevent excessive motion in response to gusts of wind.

B. Active (Electrical) Solar Tracking System: **To**

increase the output power of solar panel, an active solar tracker based on the horizon coordinate system of solar has been developed. The solar horizon coordinate system used to determine the position of the sun at every single time, thus the solar panel's position to the sun is more precise.

C. This is done using sensors that are sensitive to light such as light depended resistors (LDRs). Their voltage output is put into a microcontroller that then drives actuators to adjust the position of the solar panel.

Classification Based on Freedom of Motion

A single-axis solar tracking system **uses a tilted PV panel mount and one electric motor to move the panel on an approximate trajectory relative to the Sun's position**. The rotation axis can be horizontal, vertical, or oblique.

Single axis tracking simply means there is one axis of rotation. The axis can be horizontal (most common), tilted, or even vertical. A horizontal single axis tracker is the most common configuration. The axis of rotation is horizontal, usually orientated North-South with the modules facing toward the East in the morning and the West in the afternoon. It is common for the maximum allowed angle to be 45 degrees from horizontal. Thus in the early morning and late afternoon the tracker does not move and remains at a 45° tilt angle. Some tracking systems use "backtracking" to avoid row-to-row shading. This means that in the beginning and end of the day, the tracker reverses direction

D. Dual Axis Tracking System: The dual axis trackers **collect energy from the sun from the East, West, North, and South angles**. They function on two axes – 'primary' and 'secondary'. One axis helps the solar tracker to move from East to West, and the other helps the tracker to move from North to South.

The figure 1 below shows the classification of solar tracker system broadly.

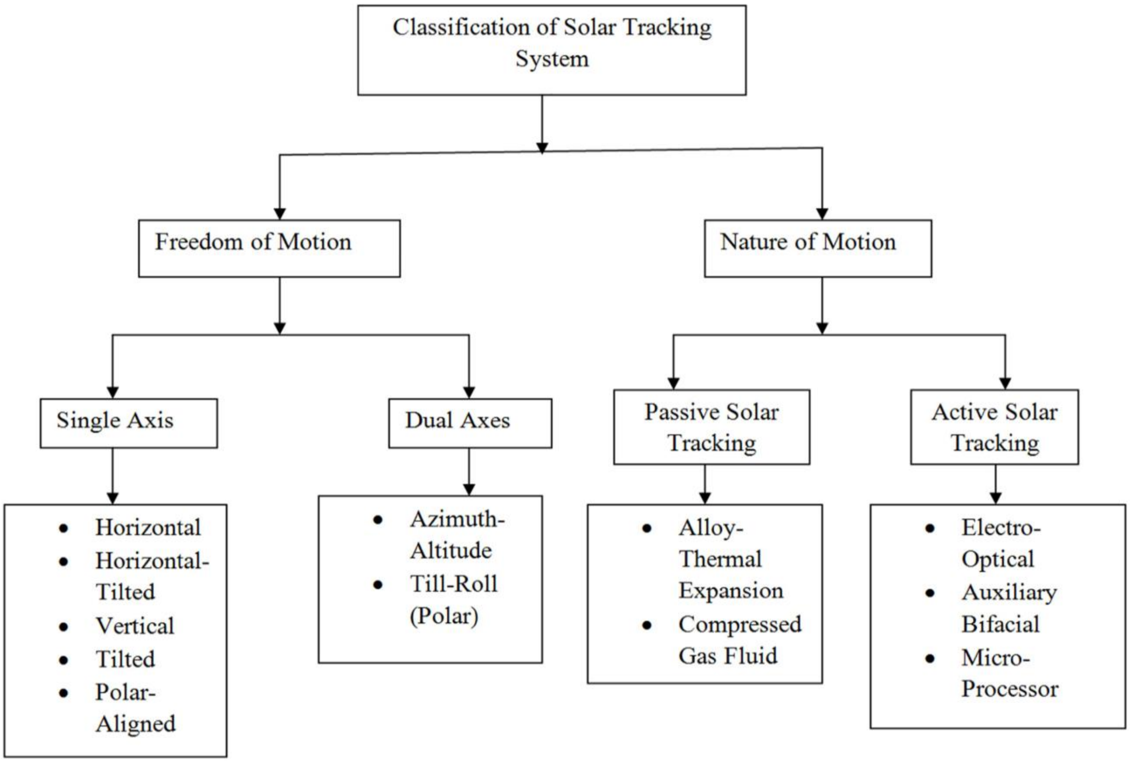

Figure 1.0: Classifications of Solar Tracking System.

CONCEPT OF DUAL AXES SOLAR TRACKER

The dual-axis tracking device tracks the sun to collect more solar energy. According to the type of axis, the dual-axis tracking device can be divided into two types: polar-axis tracking and altitude–azimuth tracking. Polar-axis tracking is also called spinning-elevation tracking.

Benefits of a Dual Axis Tracking System

A device as advanced as a dual axis tracker is bound to have advantages. So, if you're planning to buy a dual axis solar tracking system, the below-mentioned benefits will help you make an informed decision. Have a look!

- – The best part about these trackers is that they move in all directions; they can supply more energy and long hours as they track the Sun's movement. They do not wait for the sun's rays to fall on the panels. Instead, the panels follow the Sun across the sky throughout the day.
- – The dual axis solar tracker does not need a lot of space to accommodate. It can adjust in a limited space.
- – If the grid connection supplies limited power, the dual axis solar tracking system provides more energy to compensate for less power.

- – These solar trackers provide more energy – up to 40% – than their static versions.
- – These trackers are ideal in places where it is difficult to get enough solar energy, like uneven ground or stone protrusions.
- – The upfront investment cost needed for the dual-axis solar tracker is bound to pay off. This means that if this device's investment cost seems high to you as of now, the power it will create will break even the investment cost a lot sooner.

Limitations of a Dual Axis Solar Tracking System

Although blessed with many benefits, the dual-axis tracking system does have a few limitations. Make sure you consider the limitations as well before making a buying decision.

- In case of cloudy weather, the tracking system won't work as efficiently as expected.
- The dual axis solar tracking system has a short lifespan because its movable parts can get damaged.
- The maintenance cost is on the higher side because more components are involved.
- The design is a little bit complex. Hence, it might be difficult to set up these trackers. So, do not even make a DIY attempt. Rely on professionals only.

SUMMARY

- With solar tracking systems being the best option to collect more sunlight, the dual axis solar tracking system is expected to dominate the market in the future due to its high energy output. Although it has a few cons, the pros outweigh them.
- So, if you want to make a quality investment, dual-axis tracking systems are a good choice.

III. THEORETICAL FRAMEWORK

Solar energy is of extreme importance in the development of any society. It is the engine that makes the society to function. Developed countries are those whose energy resources are being put into efficient and maximum use in improving the social and economic life of their society.

The sun is a vast ball of hot glowing gas. The– temperature at the core of the sun is a high as about **15million degrees centigrade (15), but at the surface, the temperature is about 6000.**

PRINCIPLE OF OPERATION

The metal sheet is exposed to solar radiation. Sunlight passes through the glazed cover and strikes the absorber metal plate. The plate heats up changing the absorbed solar energy into heat or thermal energy. Absorber plates are commonly painted with selective coating to absorb and retain heat better than ordinary block paint. The temperature of the absorber plate rises until at the equilibrium temperature, the rate at which heat is lost from the plate. By soldering metal pipes to the metal plates, the plate is converted into a heat collector. The heat in the metal collector is then transferred to the liquid passing through the pipes attached to the absorber plates. The heated liquid is transferred to a tank for storage and use.

APPLICATION OF SOLAR PANELS

The main of solar panel technology is for providing and clean source of hot water supply.

(a) In homes with a large family or hospitals where hot water supply is in high demand for washing plates, clothing and bathing. Solar plates are a cheaper alternative than kerosene or electricity.

(b) Commercial application includes use in big laundry establishments, big hotels, car washes, military laundry facilities and in cafeteria and other eating houses. These facilities require quantities of hot water for washing various items.

(c) Solar panels are also used to heat swimming pools during cold weather and for space heating, e.g. a large hall during cold weather. There are used for operating air conditioners and refrigerators.

(d) Heat from flat plate collector or panel is used for evaporation of salt water to produce salt and for distillation of salt water or brackish water to produce clean drinking water.

(e) For electricity supply: This facility will be appropriate in Nigeria where there is abundant sunshine and utility power from the national outages. It is appropriate in area where no utility power supply is at all.

IV. PHOTOVOLTAIC PRINCIPLES

Principle of photovoltaic effect for photon to electrical energy conversion. The principle of PV effects is described such that **an electric current occurs when electrons are displaced**. For this to happen, photons (light particles) excite the outermost electrons of the atoms of certain semiconductor elements. The effect due to which light energy is converted to electric energy in certain semiconductor materials is known as **photovoltaic effect**.

This directly converts light energy to electricity without any intermediate process. For demonstrating the **photovoltaic effect** let us assume a block of silicon crystal.

The upper portion of this block is doped with donor impurities and lower portion is doped with accept or impurities. Hence the concentration of free electrons is quite high in n-type region compared to p-type region and concentration of hole is quite high in p-type region compared to n-type region of the block. There will be a high concentration gradient of charge carriers across the junction line of the block. Free electrons from n-type region try to diffuse to p-type region and holes in p-type region try to diffuse to n-type region in the crystal. This is because charge carriers by nature always tend to diffuse from high concentration region to low concentration region. Each free electron of n-type region while comes to the p-type region due to diffusion; it leaves a positive donor ion behind it in the n-type region.

This is because each of the free electrons in n-type region is contributed by one neutral donor atom. Similarly when a hole is diffused from p-type region to n-type region, it leaves a negative accept or ion behind it in p-type region

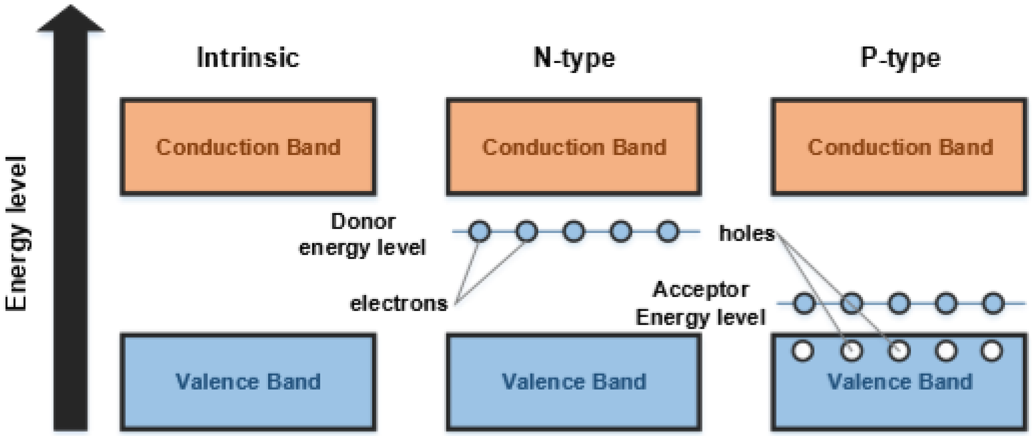

Figure 1.1: Excitement energy levels in intrinsic and doped semiconductor.

As figure 1.1 also shows, n-type semiconductors contain extra amount of loose electrons from donor, and p-type semiconductors lack some electrons in their covalence bonds.

Since each hole is contributed by one acceptor atom in p-type region. Both of these ions i.e. donor ions and acceptor ions are immobile and fixed at their position in crystal structure. It is needless to say that those free electrons of n-type region which are nearest to the p-type region first diffuse in the p-type region consequently create a layer of positive immobile donor ions in the n-type region adjacent to the junction.

Similarly those free holes of p-type region which are nearest to the n-type region first diffuse in the n-type region consequently create a layer of negative immobile acceptor ions in the p-type region adjacent to the junction. These positive and negative ions concentration layer creates an electric field across the junction which is directed from positive to negative that in from n-type side to p-type side. Now due to presence of this electric field charge carriers in the crystal experience a force to drift according to the direction of this electric field. As we know the positive charge always drift in the direction of electric field hence the positively charged holes (if any) in n-type region now drift to the p-side of the junction. On the other hand, negatively charged electrons in p-type region (if any) drift to n-region as negative charge always drift opposite to the direction of electric field. Across a p-n junction diffusion and drift of charge carriers continues. Diffusion of charge carriers creates and increases the thickness of the potential barrier across the junction and drift of the charge carriers reduces the thickness of the barrier. In normal thermal equilibrium condition and in absence of any external force, the diffusion of charge carrier is equal and opposite of drift of charge carriers hence the thickness of potential barrier remains fixed.

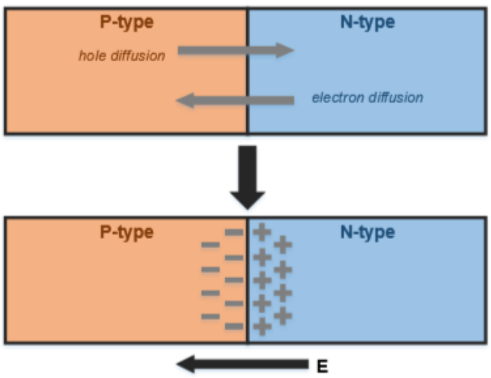

Figure 1.2: Depletion region and electric field E created by diffusions of electrons and holes in P-N junction.

The depletion region in figure 1.2 contains positive charged part of n-type and negative charged part of p-type semiconductors. This creates an electric field that prevents further diffusion of electrons and holes, reaching equilibrium. This process produces an electric current that drive the load, as shown in figure 1.3.

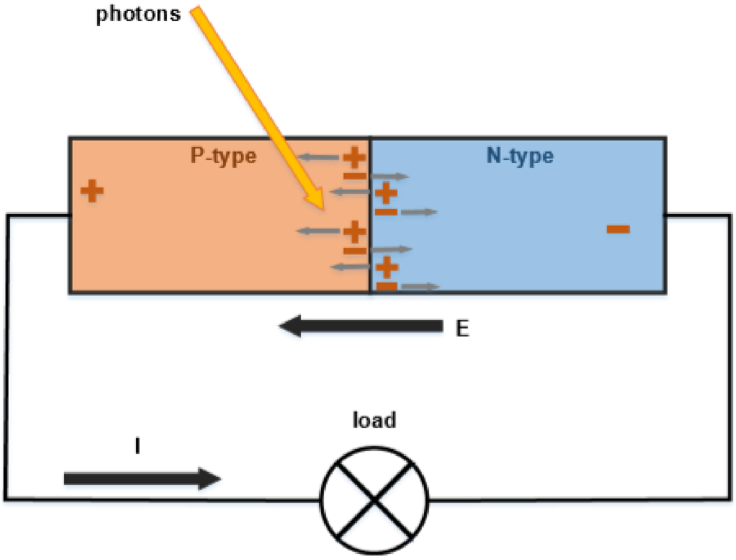

Figure 1.3: Occurrence of electric current I when an external circuit was connected to a P-N junction.

The effect explained in figure 1.3 is called the photovoltaic effect.

The semiconductor (silicon) is so doped that the p-n junction forms in very close vicinity of exposed surface of the cell. If an electron hole pair is created within one minority carrier diffusion length, of the junction, the electrons of electron-hole pair will drift toward n-type region and hole of the pair will swept to p region due to in influence of electric field of the junction and hence on the average, it will contribute to current flow in an external circuit.

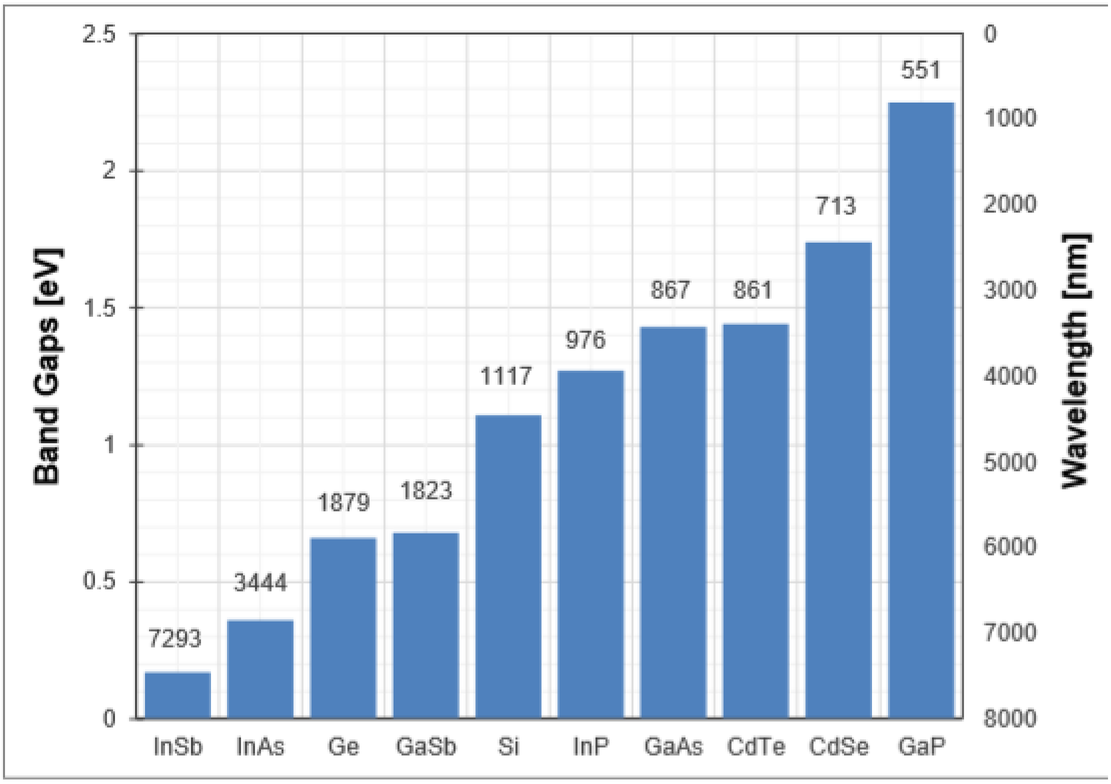

Figure 1.4. Band gap levels of typical semiconducting materials and corresponding light's wavelength values.

Among the materials mentioned in figure 1.3, the most popular type of PV material is silicon (Si), due to its photovoltaic characteristic and availability. Silicon material is chemically purified from silica sand into the form of crystalline silicon (c-Si), either monocrystalline or polycrystalline.

V. SOLAR PHOTOVOLTAIC SYSTEM STRUCTURE

A photovoltaic (PV) system is **composed of one or more solar panels combined with an inverter and other electrical and mechanical hardware that use energy from the Sun to generate electricity**. PV systems can vary greatly in size from small rooftop or portable systems to massive utility-scale generation plants.ss

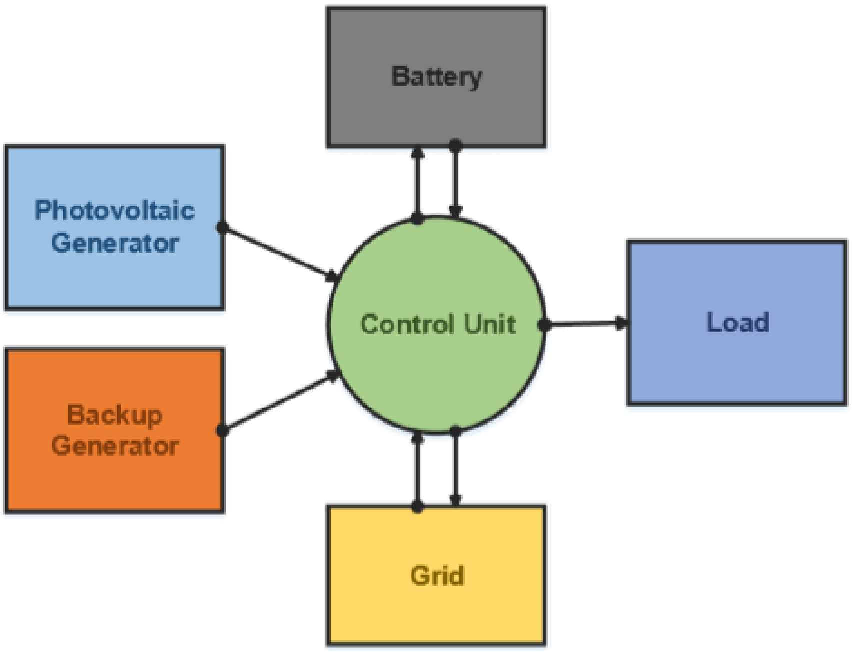

Figure 1.5. Typical components/subsystems of a solar PV system.

The light from the Sun, made up of packets of energy called photons, falls onto a solar panel and creates an electric current through a process called the photovoltaic effect. Each panel produces a relatively small amount of energy, but can be linked together with other panels to produce higher amounts of energy as a **solar array**. The electricity produced from a solar panel (or array) is in the form of direct current (DC). Although many electronic devices use DC electricity, including your phone or laptop, they are designed to operate using the electrical utility grid which provides (and requires) alternating current (AC). Therefore, in order for the solar electricity to be useful it must first be converted from DC to AC using an **inverter**. This AC electricity from the inverter can then be used to power electronics locally, or be sent on to the electrical grid for use elsewhere.

VI SOLAR MODULE'S PERFORMANCE AND SOLAR TRACKING SYSTEM

It is an advanced sun monitoring system that can rotate the panels to track the movement of the sun across the sky. It facilitates the panel system to trap the maximum sunlight and optimise the energy output. There are considerable advantages to using a solar energy tracker.

. As a result, the power P collected by solar panels can be calculated using equation 1: $P = P_{max} * \cos(i)$, (1)

Where Pmax is the maximum power collected when solar panel is correctly aligned. From equation (1) we can calculate the loss of power a:

$a = P_{max} - P_{max} * \cos(i)/p_{max} = 1 - \cos(i)$ (2).

Equation (2) tells that the more misaligned angle is; the more sunlight energy is lost.

Enhancement by Using Tracking Systems: As discussed above, fix mount options have many drawbacks for the performance of a solar PV system. Solar trackers are able to solve the core problem by minimizing the misaligned angle between sunlight's direct beams and the panels. Using different means of mechanical modules, solar trackers can rotate the panels to the optimized position throughout the whole operation of the system. Comparison of solar trackers' features to fixed mount is explained in table 1.0.

Table 1.0: Advantages and disadvantages of trackers over fixed mounts

Advantages	Disadvantages
Higher overall efficiency	More complicated design
Higher accuracy	Higher cost
Longer active functioning time	Worse tolerance against weather condition
Better lifetime for solar cells	Consumption of energy (active trackers)
Applicability for different applications	

Active trackers on the other hand, utilize motor system to control the movement of panels in single- or dual- axis, by observing the Sun's position using photo sensors. The operation of this type of trackers is managed by controller or computer. Active trackers normally cost more to the system, but provide the best accuracy and efficiency compared to the other solutions. A dual-axis tracker (DAT) can provide additional 40% of solar energy over the year, compared to normal fixed mounting system.

VII. ACTIVE SOLAR TRACKERS

Among the introduced solar tracking systems, active solar tracker is the chosen topic of research for this project, because of its extensive utilization of electrical and electronic knowledge. It is also the most implemented solution for capturing the sunlight of PV systems. Together with better manufacturing technologies of PV materials, enhancing the operation of active solar trackers is the most efficient way to better exploit the immense energy amount of the Sun.

Based on rotation of solar modules, active solar trackers can be categorized into two main types: single-axis and dual-axis.
- Tilted single-axis tracker (TSAT)
- Horizontal single-axis tracker (HSAT)
- Vertical single-axis tracker (VSAT).

SATs provide reasonably good balance between flexibility, simplicity and performance. Different configurations of SAT are illustrated in figure 1.5.

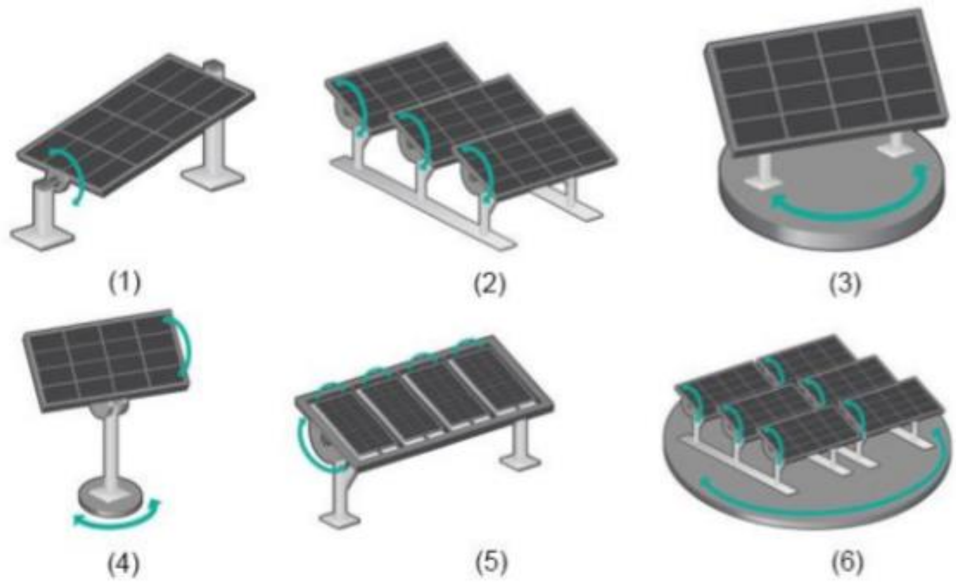

Figure 1.6: Typical configurations for active solar tracking systems: (1) TSAT (2) HSAT (3) VSAT (4) TTDAT (5) HDAT (6) AADAT

Figure 1.6 also shows three typical configurations of DAT in the bottom pictures:
- Tip-tilt dual-axis tracker (TTDAT)
- Horizontal dual-axis tracker (HDAT)
- Azimuth-altitude dual-axis tracker (AADAT).

It is necessary to clearly understand the term efficiency in the context of tracking system enhancement. Of course DATs cannot increase the "radiation-to-power" efficiency of solar PV materials, but such mounting systems help making the best out of current material technologies. The work of this project will be focusing on implementation of a small-scale AADAT, based on what have been researched about its structure and operation. The work will be carried out using mainly electronic components and equipment.

VIII. EMPIRICAL STUDIES

As mentioned dearly, solar tracking system can be passive or active solar tracking systems, these tracking systems can track the sun beam in one direction (single) axis tracking or two directions (dual) axis tracking. The following are past researches on solar tracking system:

In 2014, Kamala and Alex developed fully automated environment sensitive solar tracking system to maximize solar energy harvesting economically and efficiently. The Mechanical system with gear wheel assemble Dona frame for maximum efficiency, friction must be minimum for the, which is fixed to the frame using10mm ball bearings. To minimize the maintenance of the system, sealed bearing are used otherwise periodic lubrication is required for proper working of the system. In 2012, M. Serhan and L. El-Chaar designed two axes sun tracking system. The system tracks the sun autonomously in altitude and azimuth. Two AC motors move and 80watts panel mounted on the mechanical structure.

A cylindrical solar cooker with two axes sun tracking system was designed, constructed and operated by E. Abdallahetal. The mechanical system which consists of two parts, one for altitude tracking and another for rotating around vertical axes was based on driven motors as shown in figure8.

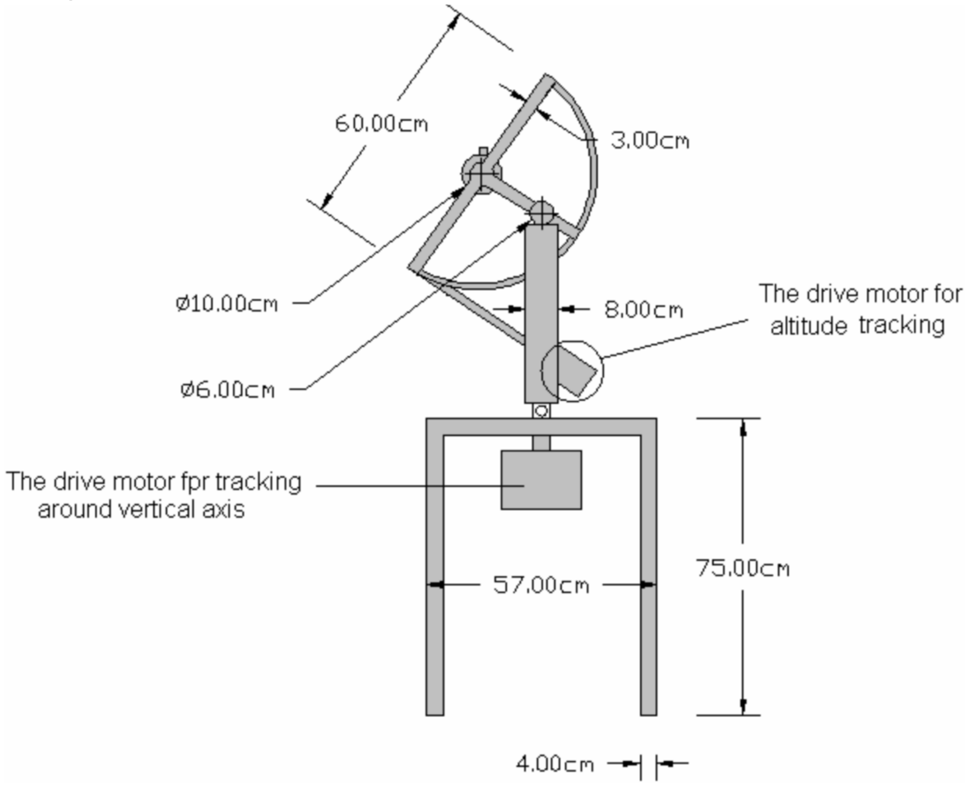

Figure 1.7: Cylindrical Solar Cooker Side View Rayetal.

Designed two ways of rotating freedom solar tracker using ADC of microcontroller. The light detecting system consists of five light depended resistors (LDR) which are LDR1, LDR2, LDR3, LDR4 and LDR5 represent as S1, S2, S3, S4 and S5 respectively mounted on the solar panel and placed in an enclosure. The sensors are setup in such a way that LDR1 and LDR2 are used to track the sun horizontally for drive the horizontal positioning motor while LDR3 and LDR4 are used to track the sun vertically for drive the vertical positioning motor. All the operations are operated by control box where microcontroller and motor control ICs process whole detection and control system. Bortolini et al.. On the contrary, azimuthal chain drive system was close to the bottom of the vertical pillar and the transmission of motion was made thanks to a vertical shaft coaxial to the pillar and placed inside it.

In 2015, S. Lo et al. The operating method of the 6.24kW pi PVDAT follow a simple pull and release of the steel cables connecting the corners of the PV module frame to the electric motors and directed by an electronic control system. The steel cables attached to the corners of the module frame also provide an extra stability in the event of high wind ofupto220km/h.

The accuracy of the tracking effect is managed by anastronomical algorithm thatenablesafull360° azimuth rotation and altitude tilt of −40° to 40° (0 = horizontal).

Performance evaluation of the iPV DAT installed and operated in Taiwan for 12 months is compared with a fixed-tiltPVsystem.Anaverageelectricitygainof30.1%and performance ratio of 93% are realized using iPVDAT.

IX. SUMMARY OF REVIEW OF RELATED LITERATURE

From the past works reviewed in 2.3 above, shows that the efficiency of Solar tracking are way better than that of the fixed mounted solar panels. But then the limitation of solar tracking has an heavily effect which includes that even with the advancements in reliability, there is generally more maintenance required than a traditional fixed rack, though the quality of the solar tracker can play a role in how much and how often this maintenance is needed.

X. MATERIAL AND METHOD

The material and method used in this work are contained in this portion of the report. It explains the development processes, the circuit diagram and its explanation, how the work was built, and how the test was conducted.

MATERIALS AND EQUIPMENT

This work is a combination of software and hardware. The hardware used to realize the works are listed below: **Solar Panel:** A solar cell (also known as a photovoltaic cell or PV cell) is an electrical device that converts light or sun energy into electrical energy through the photovoltaic effect. Solar cell electrical characteristics such as current, voltage or resistance – vary when exposed to the sun. Individual solar cells are combined to form modules commonly known as solar panels. The common single junction silicon solar cell can produce a maximum open circuit voltage of approximately 0.5 to 0.6 volts but when the individual cells are combined into a large solar panel, considerable amounts of renewable energy or current can be generated. The solar cell produces direct current (DC) power, which fluctuates with the intensity of the radiated light, the DC power is further regulated by the charge controller to a desired voltage suitable to charge the 12V DC batteries.

Charge Controller

A solar charge controller is **used to keep the battery from overcharging by regulating the voltage and current coming from the solar panel to the battery**. It is programmed at 15-A/200-W unit and uses MPPT (maximum power point tracking) to accelerate solar charging of the battery up to 30% per day. **Charge controllers aren't necessary for all solar panel systems** – but they are necessary for any solar-plus-storage system that is off-grid. They provide the essential function of preventing batteries from overcharging and discharging when panels are not in use.

DC Motor: direct current or DC electricity so it can be used by motors that run on dc electrical power.s

. Once you connect the solar panels, the power produced by the solar panel reaches the battery system first, charging the batteries for later use, and then the motor runs on the power from the battery or batteries. Without a battery system, the motor is subject to the fluctuating rate of current from the solar panel.

Batteries

Your solar PV system will not operate during a power outage without a battery. The 26% tax credit for solar applies to energy storage, as long as the battery is being charged by the solar panels. We will provide you all the information you need to maximize the tax benefits of your solar installation.

A solar battery is a device that you can add to your solar power system to store the excess electricity generated by your solar panels. You can then use that stored energy to power your home at times when your solar panels don't generate enough electricity, including nights, cloudy days, and during power outages. Lithium-ion batteries are the most popular form of solar batteries. Lithium-ion batteries work through a chemical reaction that stores chemical energy before converting it to electrical energy. The reaction occurs when lithium ions release free electrons, and those electrons flow from the negatively-charged anode to the positively-charged cathode. This movement is encouraged and enhanced by lithium-salt electrolyte, a liquid inside the battery that balances the reaction by providing the necessary positive ions. This flow of free electrons creates the current necessary for people to use electricity. When you draw electricity from the battery, the lithium ions flow back across the electrolyte to the positive electrode. At the same time, electrons move from the negative electrode to the positive electrode via the outer circuit, powering the plugged-in device. Home solar power storage batteries combine multiple ion battery cells with sophisticated electronics that regulate the performance and safety of the whole solar battery system. Thus, solar batteries function as rechargeable batteries that use the power of the sun as the initial input that kick starts the whole process of creating an electrical current.

Microcontroller

The Arduino microcontroller acts as the main controller of the whole system. Solar Module for Arduino is a small board that can power your Arduino board, to get a totally autonomous outdoor board. It includes a 3W solar panel that provides 5V to your Arduino board, and an 1100 mAh Li-Ion battery.

Light Dependent Resistor (LDR)

An LDR (Light dependent resistor), as its name suggests, offers resistance in response to the ambient light. The resistance decreases as the intensity of incident light increases, and vice versa. In the absence of light, LDR exhibits a resistance of the order of mega-ohms which decreases to a few hundred ohms in the presence of light. It can act as a sensor, since a varying voltage drop can be obtained. When the light level is low the resistance of the LDR is high. This prevents current from flowing to the base of the transistors. Consequently the LED does not light.

Bearing

Solar tracker bearings allow for the rotation of solar panels so that their angle is maximized in relation to the sun. Bearings are the devices that connect the moving parts of a tracker including the modules with the stationary posts or piles. The lower part of the bearing is attached to a galvanized steel post, and the upper part moves along with the table, the modules and the structure which holds them as the table is driven from east to west by a motor or another type of actuator. Between the lower and upper part of the bearing, there is some wear surface or roller, a material which experiences friction and which may wear over time. The key to the bearing's function and reliability. The bearing allows the tracker's table to move smoothly and with minimal friction. The bearing also defines the motion.

Flexible Conduit

Conduit used in solar installations is generally divided into two categories: rigid and flexible. Each category can be further divided into metallic and non-metallic types. Non-metallic conduit is made from plastics that have to meet the performance requirements of steel while being much lighter, using materials like Nylon, polypropylene or PVC. Metallic conduit can be made from galvanized steel, stainless steel, brass, aluminum or nickel-plated brass. Some contain both metallic and non-metallic materials to offer low fire hazard and anti-static capabilities, external braiding and other features.

Patters Box

Patters or patters box or fitting box is the container for the space behind electrical fittings such as power outlet sockets, light switches, or fixed light fixtures. Pat tresses may be designed for either surface mounting (with cabling running along the wall surface) or for embedding in the wall or skirting board. The patters box was added as an output to show the efficiency of the solar tracking system.

Steel

this is a compound of iron and carbon. It is used to construct the frame of the solar tracker.

Relays

These are electromechanical switches. They are used to switch on or off the electric motors.

Transistors

They are P-N devices that are used to control the flow of current through the energizing coils of the relays.

Resistors

They are used to limit the flow of current through a component.

Vero board

It is a circuit board on which electronics components are soldered to construct a circuit.

Jumper Cables

They are used to conduct current from one component to another.

Contact Switches

The Contact Switch performs the switch function by mechanically switching contact points. They serve as limit switches in this project.

Soldering iron

A soldering iron is a hand tool used to heat solder, from an electrical supply at high temperatures above the melting point of the metal alloy. This allows for the solder to flow between the work pieces needing to be joined.

Tin Lead

The tin lead wire solder is used for electronics to ensure that electronic components are joined securely to contact points.

Bolts and nuts

Bolts and nuts are used for joining the metal construction. The bolt consists of a cylindrical shank with a head. The shank is threaded for a nut.

A laptop computer

It is used in this project to write the code that runs on the microcontroller.

BLOCK DIAGRAM DESIGN

The block diagram consists of seven blocks. Each block represents an electrical circuit. This is shown in Figure 1.7.

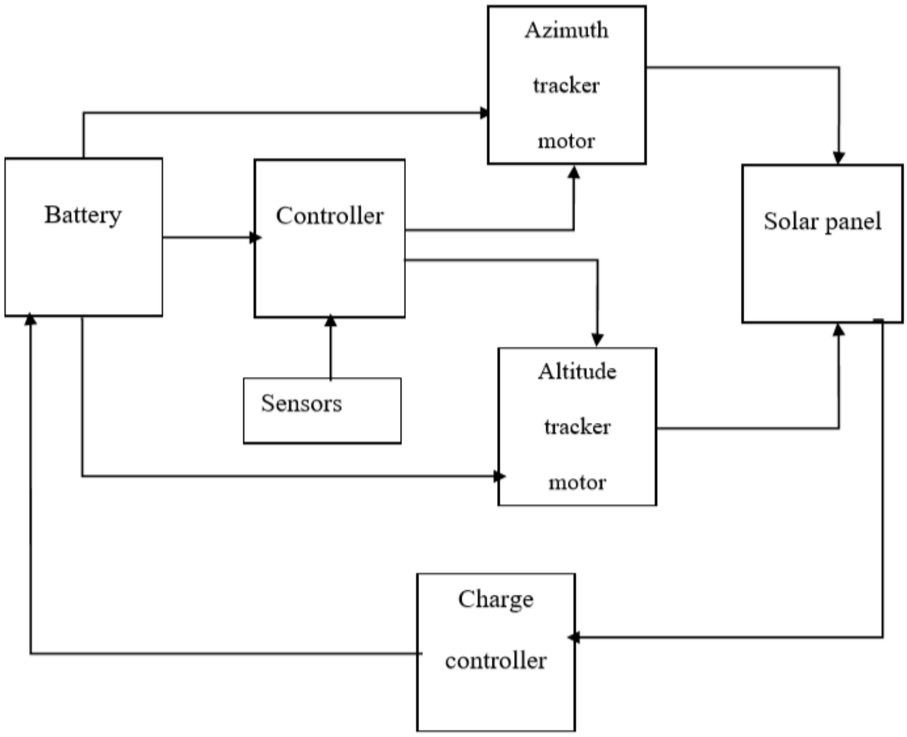

Figure 1.7. Block diagram of the dual axis solar tracker

RATINGS
Battery: 12V
IC Controller: 5V (with a step-down regulator embedded inside)

Solar Panel
Peak Power (PMP) ------ 120Wp
Production Tolerance---- + or – 3%
Maximum Power Current (IMP) ---6.66A
Maximum Power Voltage (VMP) ---18V (depends on the maximum peak of the sun)
Maximum System Voltage---------1000VDC
Open Circuit Voltage------------21.6V
Sensors: (Analog sensors where used and they read in range of value that is, it is sun dependent or light dependent).
Max Output -----------5V
Charge Controller: 12V IC connected to the Battery.

Microcontroller
Has 3V - 5V input for HIGH and output of 5V 0V – 2.8V input for LOW and output of 2.8V
The solar tracker's control system is powered by two batteries. They fuel the motors and the controller that turn the apparatus to follow the sun. The C ++ programming language is used to program the controller. While the azimuth tracker follows the sun as it rotates from north to south throughout the year, the altitude motor rotates to follow the sun as it moves from east to west throughout the day. The battery that powers the system is recharged with some of the power produced by the solar panel.
The project has two tracking systems: the azimuth tracking system that tracks the yearly movement of the sun and the elevation tracking system that tracks the daily movement of the sun. to track the sun yearly, the following calculation is made:

$$Sun\ speed\ \left(\frac{degree}{min}\right) = \frac{\nabla Sun\ Angle\ (degree)}{\nabla time(minutes)}$$

A motor that turns 3600 degrees will give rotation according to equation (4). $Sun\ speed\ (rpm) = (Sun\ speed\ (degree/min))/360^0$ (5)
The Sun rotates 360^0 in 1440 minutes. This gives 0.25^0 per minute.
Minimum rotation speed of the Sun = 0.25 / 3600 = 0.0006944rpm. There is practically no electric motor that turns with such an rpm. As seen in Figure 10, the Sun moves 180 degrees approximately in a year, from January to December, from North to South. This gives a speed of 0.0006944rpm/2 = 0.0003472rpm.
The motor used in this project has a speed of 65rpm. With respect to the speed of the Sun, it will have a ratio of 65/0.0003472. That is 187211.9816:1, which means that the

motor covers 187211.9816 revolution while the earth does 1 revolution. The motor has a revolution in 1.083333333 seconds. To make the motor move with the speed of the earth, the period will be divided by a constant of 187211.9816.

Period = 1.083333333 / 187211.9816 = 0.000005786 seconds

With this period, the speed of the motor in a minute will be 0.000005786 x 60 = 0.0003472rpm approximately.

The motor is designed to run with a pulse width modulation with duty cycle of 70%. That is, the pulse will be high 70% of the period for the motor to make a revolution.

The angle of elevation is controlled with sensors that are used to track the sun during the day.

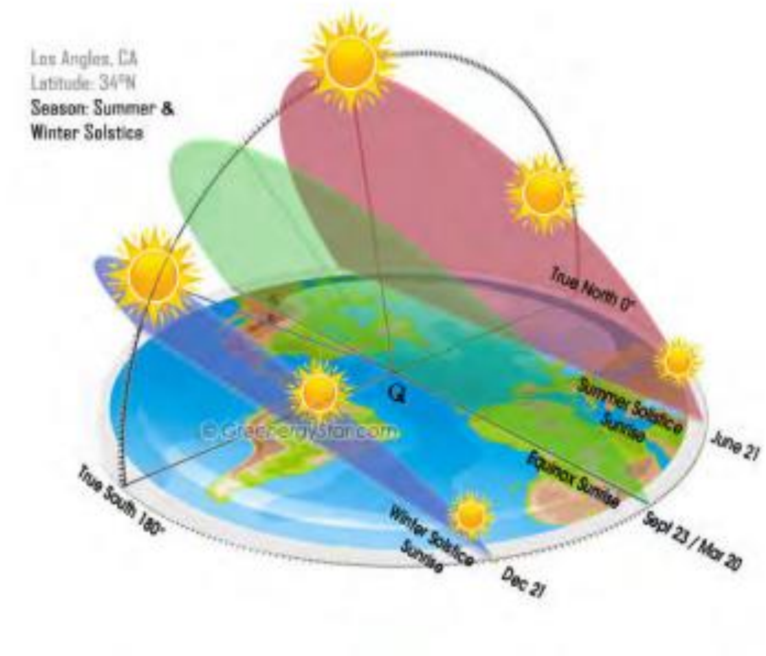

Figure 1.9. Direction of the earth rotation.

CIRCUIT DIAGRAM AND THEIR DESCRIPTION

Figure 2.0 is the circuit diagram of the Azimuth tracker in the system. It has a microcontroller that controls the direction of the motor that turns to track the sun.

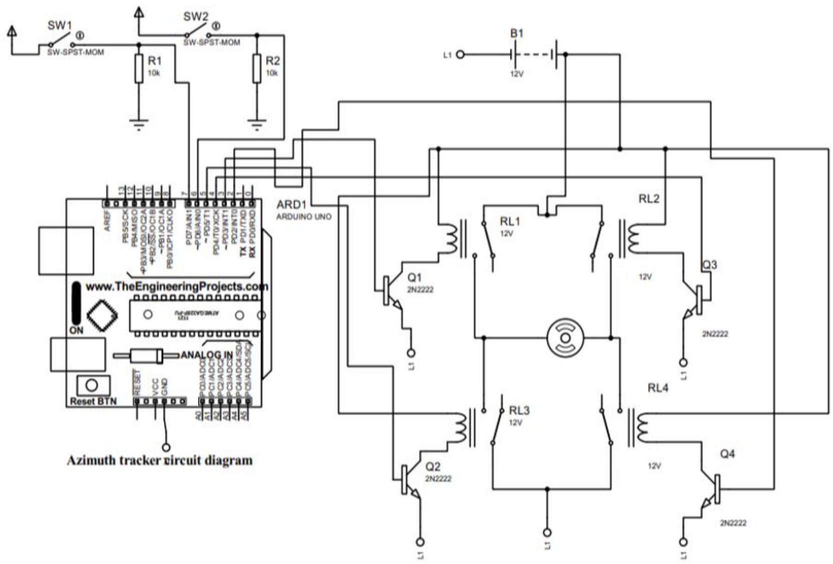

Figure 2.0. Circuit diagram of Azimuth tracker.

An Arduino microcontroller is used in the development. On the implemtation there are two switches that terminate the movement of the tracker North to South and vice versa. The resistors R1 and R2 are pull down resistors that keep the levels of the switches LOW. The transistors Q1, Q2, Q3, and Q4 are solid state switches that put off or put on the relays. At each time, either Q1 and Q4 are HIGH or Q2 and Q3 are HIGH. When any of these pairs are HIGH the motor move in a particular direction. If it moves North for Q1 and Q4, then it will move south for Q2 and Q3. In this way the direction of the tracker changes towards North or towards South. The switches SW1 and SW2 are used to terminal the movement of the motor at both ends of North and South.

In Figure 2.1, the circuit diagram for the elevation tracker is shown. This tracker tracks the movement of the sun during the day, from east to west.

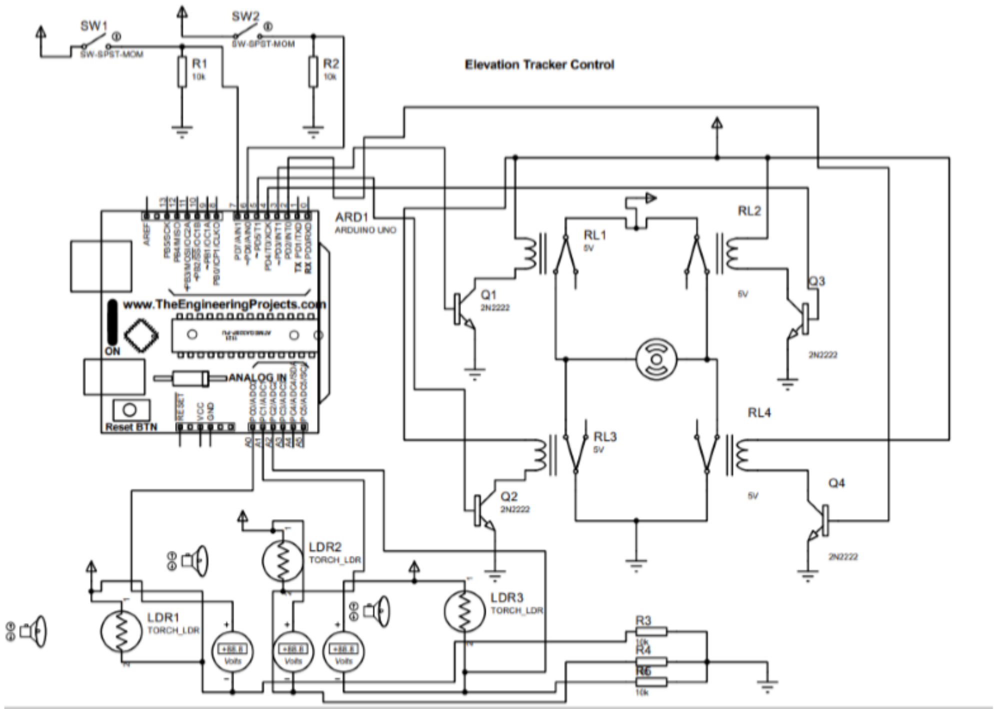

Figure 2.1. Elevation tracker system

In the diagram of Figure 2.1, there are three photo sensors incorporated in the circuit. These three sensors determine the position of the solar panel during the day. When it is morning, the sun is at an angle in the east so that the sensor at that angle gets more photons and so keeps the solar panel in that direction. When the sun changes direction at noon, the sensor at that point gets more photons and so the solar panel is moved so that it faces the sun to get maximum energy. When the sun is setting, the sensor at that direction moves the solar panel to align with the sun too, and the cycle continues like that every day. The movement of the motor is controlled by a pair of relays: RL1 and RL4 are a pair that keeps the motor moving a one direction and the other pair RL2 and RL3 are the other pair that keeps the motor moving in the other direction. The switches SW1 and SW2 are used to terminal the movement of the motor at both ends of East and West.

XI. EXPERIMENTAL METHODS

First, the system's framework was built. The frame is constructed from steel. The system's base measures 46 by 86 cm. It has a rectangular base. The solar panel is rotated azimuthally by a motor that is housed there. The base and the top are the two halves of the framework. The solar panel is supported in the top section in such a way that it may rotate from east to west courtesy of a motor. The base records the movement of the sun throughout the year as it moves from north to south, while the top rotates the solar panel in the angle of elevation to track the sun as it moves from east to west during the day.

After the working on the frame is done, the electronics circuit is constructed on a vero board with a tin lead and a soldering iron, following the circuit diagrams.

The pictures of the project are shown in Figure 2.2, Figure 2.3 and Figure 2.4 as different view of the dual axis solar tracker.

Figure 2.2. Front view dual axis solar tracker

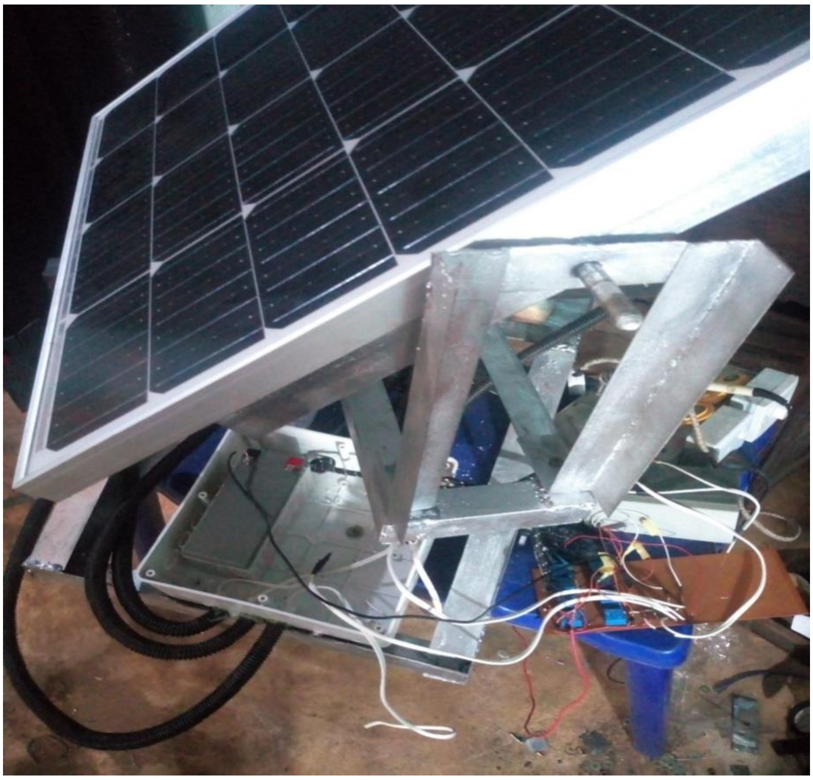

Figure 2.3. side view of dual axis solar tracker

Figure 2.4. End view of dual axis solar tracker.

To determine the efficiency of the dual axis solar tracker, the voltage levels of the solar panel are obtained when it is stationary and light energy falls on it and when it tracks light energy. The values obtained are plotted on a graph. The result of the test is given in page.

XII. RESULT AND DISCUSSION

RESULTS OBTAINED

The solar panel's voltage levels vary depending on whether it is tracking light energy or not, as shown by the graphs in Figures 2.5 and 2.6, respectively. Estimated hours are from 6 am until 6 pm (12 hours). The sole factor used in the test is the angle of elevation. This is due to the fact that monitoring the Sun annually in azimuth would require a substantial amount of time, which is limited by the time required for work presentation.

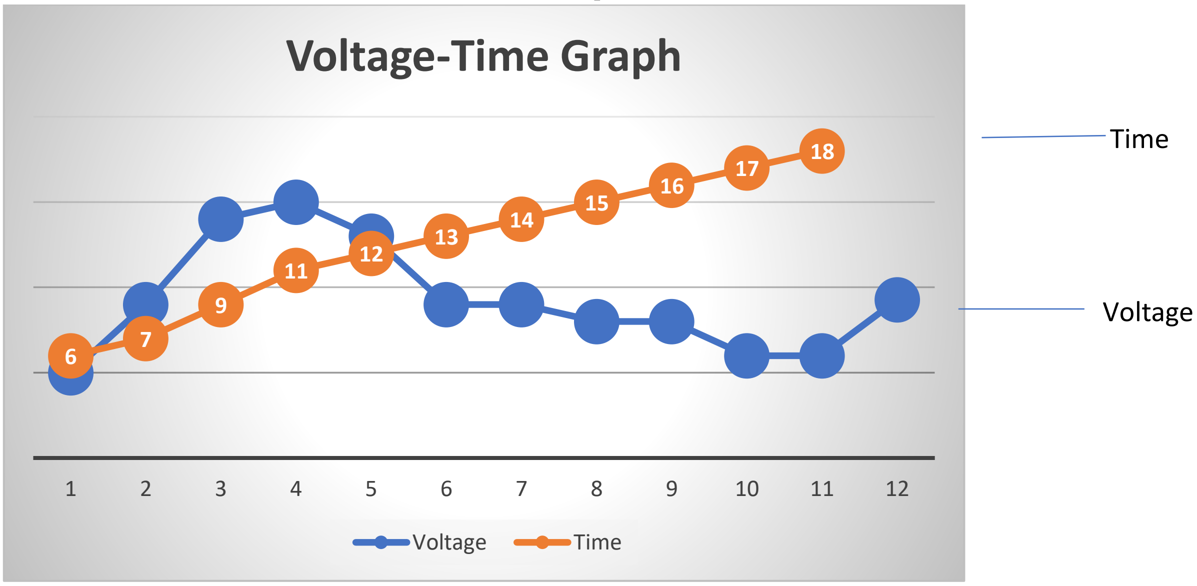

Figure 2.5. Voltage levels of a stationary solar panel.

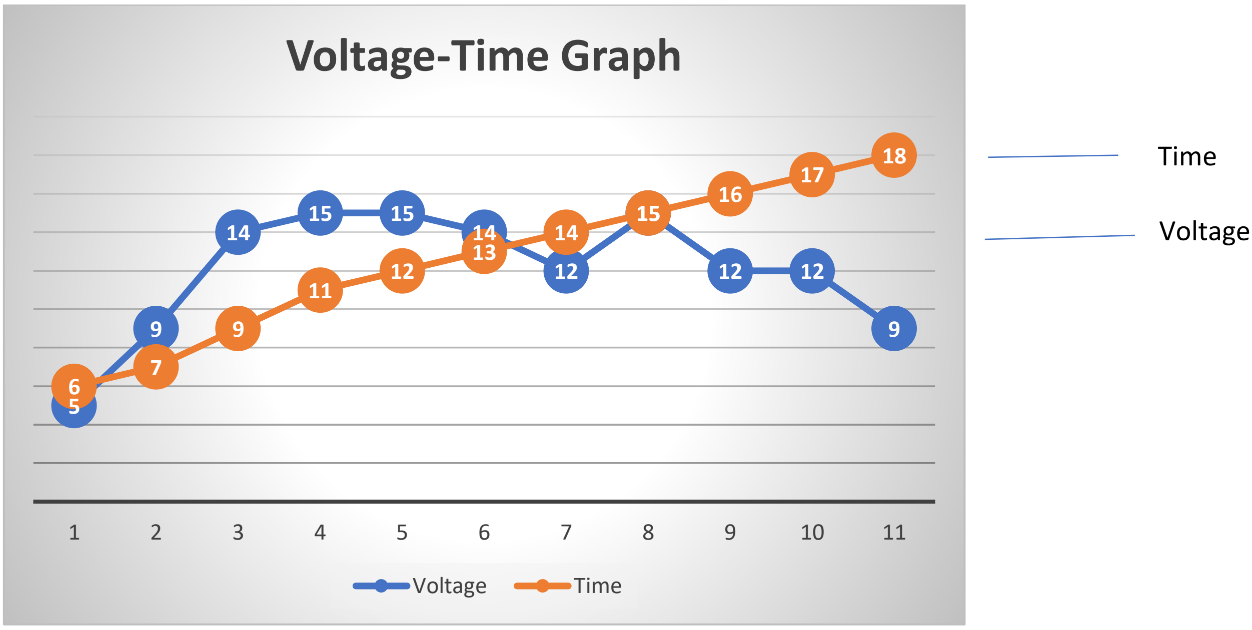

Figure 2.6. Voltage levels of a tracking solar panel.

Average voltage level without tracking system = 9.272727 V

Average voltage level with tracking system = 12 V

Percentage increase = $\frac{12-9.272727}{12}\ x\ 100 = 22.7\%$

Other results for the project were gotten from LDRs for the solar tracking system and the panel that has a fixed position. The results were recorded 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 and 1 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 board. To collect the results, a code was written that made it possible to collect data from the LDRs after every one hour.

Table 1.1. Photovoltaic array outputs for bright sunny day

Time (Hrs)	PV Array Output (V)	
0600	08.25	
0700	08.95	
0800	09.52	
0900	09.89	
1000	10.33	
1100	10.76	
1200	11.00	
1300	10.82	
1400	10.56	
1500	10.32	
1600	10.08	
1700	09.26	
1800	08.34	

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. The light intensity is directly proportional to the power output of the solar panel

Table 1.2: LDR Outputs for cloudy day

Time (Hrs)	LDR1(V)	LDR2 (V)
0630	0.277	0.276
0730	0.504	0.509
0830	1.757	1.933
0930	1.631	1.783
1030	1.900	1.798
1130	2.910	2.969
1230	1.990	1.990
1330	1.985	1.990
1430	0.976	0.985
1530	0.941	0.892
1630	0.824	0.594
1730	0.128	0.981
1830	0.982	0.968

XIII. DISCUSSION OF RESULTS

The voltage of a solar panel depends on the amount of light energy present that day, but as the research demonstrates, light energy can be better captured with the aid of a tracking device.

The rate at which photons leave the sun and travel to the earth is not constant throughout the day; it varies with the passage of time and is also influenced by the position of the solar panel on the planet. The tracking system provides a higher voltage level during the daytime because of this. If the solar panel is put in a location where it would receive a daytime shadow from something, it might not generate enough electricity at that time.

From the summary shown by the graphs in figure 2.5 and figure 2.6, respectively, Both the average voltage without tracking system and the average voltage with tracking system achieved better result for the solar tracking system. However, the proposed average voltage with tracking system outperformed the average voltage without tacking of both in photovoltaic and LDRs output. The average voltage without tracking system is 9.27V and average voltage with tracking system is 12V. The average voltage with tracking system outperformed the average voltage without tracking system by 2.73V. This show that the average voltage with tracking system achieved better result than the voltage without tracking system, finally the percentage increase is 22.7%.

SUMMARY

Solar trackers are used to maintain solar panels pointed directly towards the Sun throughout the Sun's daily ascent and descent. Sun trackers are used to increase the solar energy that is received by the solar panel and enhance the energy output of electricity generated. In addition to tracking the sun's journey from east to west, the dual-axis solar tracker also records the sun's angular height position. Dual-axis systems operate similarly to single-axis systems, but by spinning their axes along vertical and horizontal axes, they are better able to capture solar energy.

CONCLUSION

In this research, a dual axis solar tracker was designed and constructed. The objectives were achieved and result shows that a tracking system for solar energy gives more energy output than a fixed system. Dual-axis solar trackers are more effective in terms of electrical energy generation. In comparison to the fixed system, the gain of the dual-axis tracking system, in this work, is 22.7%.

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