PERFORMANCE TEST OF AUTOMATIC MULTI AXIS SOLAR TRACKING SYSTEM USING ARDUINO

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DECLARATION

We hereby declare that this thesis is our own work and to the best of our knowledge it contains no materials previously published or written by another person, or have been accepted for the award of any other degree or diploma at Sonargaon University or any other educational institution. We also declare that the intellectual content of this thesis is the product of our own work and any contribution made to the research by others, with whom we have worked at Sonargaon University or elsewhere, is explicitly acknowledged.

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CERTIFICATION OF APPROVAL

The thesis title "**Performance Test of Automatic Multi- Axis Solar Tracking System Using Arduino**" submitted by Md. Kamrul Islam (BME1901017171), Mainul Islam (BME1803016089), Md. Imrul Kayes Rakib (BME1901017028), Md. Mehedi Hasan (BME1901017107), Md Miraz Hossain (BME1901017269), Session 2018-19 has been accepted as satisfactory partial fulfilment of the requirement for the degree of bachelor of science in mechanical engineering on 24 January 2023.

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ABSTRACT

The solar tracking system plays a major role in which it is used to capture the maximum power from the sunlight. In Bangladesh, for both urban and rural residents, obtaining sufficient and dependable power is a key developmental problem. By using a solar tracker, the aim is to mitigate these issues by using the abundant sunlight available and to maximize efficiency by using the tracking mechanism**.** We developed the solar panel system to overcome this which shift in accordance with the direct intensity associated with the event of solar radiation. Solar power, which is available only in fixed installations, is the major problem. The ability of power that can be generated is restricted as part of this issue. Unlike fixed tilt ground mount systems, solar trackers cause solar panels to follow the sun's path throughout the day. This paper included a practical work compare the performance of different photovoltaic systems; the solar tracker system was installed in Dhaka-Bangladesh to measure the solar radiation received. The impact of the use of single axis and double axis trackers and compared this influence to fixed solar panel, a solar tracker had been constructed, the three system were tested and got a logical knowledge. The influence of each device on solar energy systems were, the single axis tracker system tends to 29.83% Improvement of power generated relative to the fixed solar panel; the dual axis tracker system tends to 37.05% Improvement of power generated relative to the fixed solar panel while double axis tracker system tends to 7.7% rise compare to the fixed solar panel.

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LIST OF ABBREVIATIONS

Words/Signs	Abbreviation
h	Hour
s	Second
V	Voltage
I	Current
P	Power
MPPT	Maximum Power Point Tracking
LDR	Light Dependent Resistor
PV	Photovoltaic
DC	Direct Current
AC	Alternating Current
VOM	Volt-Ohm-Milliammeter
USB	Universal Serial Bus

LIST OF MATHEMATICAL SYMBOLES

Symbols	Abbreviation
%	Percent
=	Equal
+	Plus
-	Minus
/	Division
×	Multiplication

Chapter 1

INTRODUCTION

1.1 Background of the Study

The solar tracking system plays a major role in which it is used to capture the maximum power from the sunlight. During those days, the power generation method is not great as now because there are many types of power generation system like nuclear power plant, hydroelectric power plants, geo thermal power plants, other non-renewable and also renewable energy source power generation methods [1]. In this paper, the solar power generation is one of the pollution free and zero emission process rather than non-renewable energy source. When trying to harness the most amount of energy from the sun, the solar tracking system is important.

Though in this time electricity is one of the most important part of our life, approximately 1.6 billion people still living without electricity [2]. It's only for the high cost of power grid building and maintains. This vast quantity of energy crisis can be meeting up by renewable energy across the In PV power systems has an important role. It's minimizing also the arrow efficiency as well as its cost is lower than the other power system. Another problem is that the position of this point is not fixed but it moves according to the irradiance, the temperature and load. Because of the relatively expensive cost of this kind of energy we must extract the maximum of watts of solar panels.

The main aim of this study is to maximize PV power and reduce CO_2 emission by implementing a highly efficient and low-cost solar tracking system. The solar tracker was designed in this work as an economical, flexible, and efficient frame-holder. A low-cost and Arduino microcontroller was used as the control unit for the proposed system, and the sun position was detected by using photo-sensors. The developed sun-tracking system captured the maximum possible amount of solar energy throughout the entire day compared with the stationary system, which only collected maximum solar energy when the sun was facing the PV panel. The experimental results prove that the efficiency of this system is especially high in morning and afternoon hours and that using a stationary panel will be ineffective due to the low radiations received from the sun during these periods.

In the last ten years, many residential areas around the world used electric solar system as a back-up power for their houses. This was because solar energy, which is the energy derived from the sun through the form of radiation, is also an unlimited energy resource and is going to become increasingly important in the long term for providing light, heat and energy to all living things. It is also related to the aspects of deforestation control, protection of ozone layer, reduction of CO2 emission and so on [3]. In order to utilize the superiority of solar energy, solar tracker was constructed for this project.

1.2 Research Problem Statement

Solar power, which is available only in fixed installations, is the major problem. The ability of power that can be generated is restricted as part of this issue. The other factor is that the solar tracking system's purchase price is very high for a family that uses more electricity than normal, so more than one solar panel will need to be installed to generate enough power [4]. So, this concept is all about solving the problem that is solar tracking system will detect rotation. Usually fixed solar energy panels would not be directly oriented towards sunlight as a result of the continuous motion of the Earth. The solar tracking device is the larger solution for achieving full output power due to this method. This is the primary reason that why the project for the solar tracker is implements. The solar tracker must obey the sunlight in order to get additional power output.

1.3 Goals and Objectives

The objectives of this project are:

- To improve the performance and efficiency of a solar panel
- To develop a system that is affordable
- To solve the imbalance problem
- To develop and fabricate the necessary model.
- To design a system that traces the sunlight for solar panels.

1.4 Scope and Limitation of the Study

A solar tracker is used in various systems for the improvement of harnessing of solar radiation We have worked on different sun angles and mainly the solar radiation for different systems. We have ignored different factors like humidity, sun intensity etc. So, here is a scope to improve it more and make it more accurate.

Commercially, dual-axis sun tracking system is still rare even in countries where a significant part of electricity is being generated by solar energy as they claim that single-axis sun tracking system is doing the job. But dual-axis sun tracking system can significantly increase the efficiency. So, there is a scope to improve the performance of single-axis sun tracking system from different aspects which will be more cost effective.

1.5 Methodology of the Study

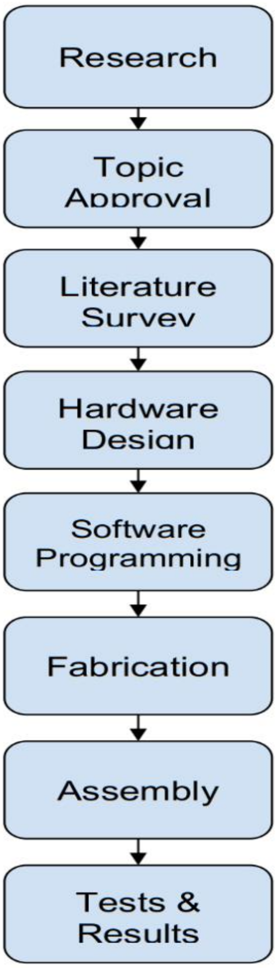

Figure 1.1 Flow chart of Methodology of the Study

Research: In Bangladesh, for both urban and rural residents, obtaining sufficient and dependable power is a key developmental problem. By using a solar tracker, the aim is to mitigate these issues by using the abundant sunlight available and to maximize efficiency by using the tracking mechanism.

Topic Approval: Upon analysis of the objectives the project was approved by the university panel.

Literature Survey: The project team reviewed multiple published papers on the concerned topic from notable websites such as ieeexplore.ieee.org, ijert.org, etc.

Hardware Design: The necessary hardware components were designed using software tools such as solid works and certain digital component designs were utilized from online resources such as Proteus.

Software Programming: The software program necessary to operate the sun tracking solar panel was modified from existing programs for single-axis tracking systems to suit a dual-axis operation using C++.

Fabrication: All the necessary custom hardware components are fabricated using 3D printing facilities.

1.6 Contribution of the Study

The solar energy plays a vital role among all this energy now. As it has a drawback that it can only generate power against the solar panel until the intensity associated with the incident of solar radiation. We developed the solar panel system to overcome this which shift in accordance with the direct intensity associated with the event of solar radiation. This can be accomplished by controlling the solar through the servo motor, the correct algorithm and the best mechanical configuration and the Arduino microcontroller. Since the effect would increase in both efficiency and low cost connected with the solar power technology. Limited sources of fossil fuels, such as petroleum and coal, which are available now leads to global warming due to CO2 emissions [5]. The alternate source of energy is needed to reduce this type of emission. Energy from renewable sources such as solar, wind, geothermal and ocean tidal waves is being increasingly required to provide a reliable power supply and a safe environment for future generations.

1.7 Arrangement of the Study

- Complementing the introduction above, a through literature review of relevant work is presented in chapter 2. The review is accompanied by the motivation of present research.

- The research design, methodology of the research and different types of solar tracking systems are discussed in chapter 3.
- Chapter 4 deals with the experiment result and analysis of the result from fixed, single axis and dual axis solar tracking system.
- Finally, the summary of observations and conclusions along with a brief reflection of future research are articulated in chapter 5.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

A through literature review of relevant work is presented in this chapter. The review is accompanied by the motivation of present research. In section 2.2 of this chapter various literature reviews are given. Then in the next section selection methods are given and at the last of this chapter description of various types of solar tracking system is given. Effects of the dust axis density on the inclination of solar panel and temperature effect on solar panel also mentioned.

2.2 Previous Research and Reports

Mohanapriya et Al., (2021), studied and investigated**,** the idea of the solar tracking device is more efficient for harnessing more energy than a fixed solar panel. The production of solar energy is much more costly than traditional energy sources, partly due to the cost of manufacturing PV modules and partly due to the conversion performance of the equipment. Solar installations can produce no power at all at any stage, which could lead to a shortage of energy if too much of the electricity in a region comes from solar power. In recent years, solar radiation tracker has played a critical role in rising the performance of solar panels, thereby proving to be a better technical feat. A dual axis solar tracker's clinical significance lies in its better efficiency and durability to produce higher performance compared to a fived solar panel or solar tracker with one single axis. The tracking system is planned so that the solar energy can be trapped in any possible direction. Therefore, the performance increases suggesting that the efficiency is greater than a fixed solar panel.

Thin Thin Hiwe in (2019), To meet our ever-increasing energy needs, solar power is emerging as a potentially inexhaustible and non-polluting energy source. Arduino prototype driven automated solar tracking system is primarily designed using Arduino Microcontroller, LDRs, and stepper motors Three phase motors are typically used to transfer solar power based on the accumulated incident light controlled by LDRS. The software controls this solar panel's vertical tilt point, and it rotates horizontally. Then according to the sunlight incident, it could follow the direction of the sun, not just the vertical rotation as well as the horizontal rotation of the solar panels. This system is therefore capable of optimal lighting and can minimize the cost of electricity production by providing a minimum number of solar panels with proper alignment with all sunlight.

Shreyasi Chakraborty et Al., in (2017). Due to their many benefits, renewable energy sources are becoming one of the top priorities for today's world. In particular, to meet our ever-increasing energy needs, solar energy is emerging as a potential source of inexhaustible and unpolluted energy. However, solar panels, which are fundamental components of the conversion of solar energy, are installed at a certain angle and with diurnal and seasonal shifts, are unable to track the direction of sunlight. Using a microcontroller combination, we built a solar tracking system.

Hossein Mousazadeh et Al., (2011), studied and investigated maximization of collected energy from an on-board PV array, on a solar assist plug-in hybrid electric tractor (SAPHT). Using four light dependent resistive sensors a sun tracking system on a mobile structure was constructed and evaluated. The experimental tests using the sun-tracking system showed that 30% more energy was collected in comparison to that of the horizontally fixed mode. Four LDR sensors were used to sense the direct beams of sun. Each pair of LDRs was separated by an obstruction as a shading device. A microcontroller based electronic drive board was used as an interface between the hardware and the software. For driving of each motor, a power MOSFET was used to control the actuators. The experimental results indicated that the designed system was very robust and effective.

Rathika Kannan. Kavitha S in (2017), Solar tracking system was made with stepper motor tracking system to increase the efficiency of output power of the PV plate. Solar energy is becoming ever more an alternative energy source. It is a device that tracks a solar array's rotation, so it is always associated with the direction of the sun Developed and mounted in this article, the solar tracker offers a safe and inexpensive way to align a solar panel with the sun to optimize its energy output. In the proper orientation the solar monitoring system is configured to align the photovoltaic solar panel with the sun for direct radiation.

Ankit Anuraj Rahul in (2018), As an important tool for renewable energy, solar energy is increasingly rising. Solar tracking helps to collect more solar energy, since a profile that is perpendicular to the sun's rays can be maintained by the solar panel.

Whilst initial costs are high for the implementation of a solar tracking device, this paper offers a cheaper solution. The control circuit of the solar tracker relies on an ATMega16 microcontroller. It is intended to sense sunlight through the LDR, and then switches with the stepper motor to align the solar panel where maximum sunlight can be obtained. The stepper motor is more controllable, more energy-intensive, more powerful and has good precision tracking and little environmental impact compared to any other motor type.

K.S. Madhu et Al., (2012) International Journal of Scientific & Engineering Research vol. 3, 2229–5518, states that a single axis tracker tracks the sun east to west, and a two-axis tracker tracks the daily east to west movement of the sun and the seasonal declination movement of the sun. Concentrates solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. PV converts light into electric current using the photoelectric effect. Solar power is the conversion of sunlight into electricity. Test results indicate that the increase in power efficiency of tracking solar plate in normal days is 26 to 38% compared to fixed plate. And during cloudy or rainy days it's varies at any level.

2.3 Solar Tracking

The majority of tracking systems on the market are systems that are active, which indicates that the tracker system is powered by electricity to turn a motor or other mechanical gear that steers the solar panels in the correct direction [5]. Passive solar trackers, on the other hand, follow the sun without using any additional energy. They move by heating gas with the sun's heat. When that gas expands, it causes the solar panels to move mechanically. When the sun moves and the air cools, the panels compress and return to their previous position. The science behind passive solar trackers is more complicated than this explanation, but we'll keep it simple for now. The essential point is that active solar trackers move by using a motor, but passive solar trackers move by using the sun.

Active solar trackers, on the other hand, are better suited for big and complicated installations, whilst passive trackers, because of their poorer accuracy, may be utilized for basic PV systems and not much more.

PV trackers are classified as active trackers or passive trackers based on their motor systems. The most common type of sun tracker is active, whereas passive solar trackers are less common. As a result of their various designs, their performance and cost differ.

2.3.1 Active solar tracker

In electrical engineering, the terms active and passive are often used. Active devices are those that need an external source of energy in order to function properly. Passive energy is defined as energy that does not need an external source of energy [6]. As a result, active trackers need the energy to move their actuators. That energy may even be part of the PV system they're driving. Motors and other complex mechanical devices may be used in actuator systems.

2.3.2 Passive solar tracker

Passive solar trackers, on the other hand, will monitor the sun without needing any extra energy, at least from us. They obtain their energy from the sun as well, but not from the one we've captured. The sun's heat is frequently used to cause a given amount of goods, such as with a low boiling point gas, to expand. The expansion causes a mechanical actuator to move. A pair or more actuators are placed in such a way that they expand differently depending on the orientation of the payload tracker with respect to the sun. As a result of differential expansion, the tracker travels closer to the sun's direction. How does it move at sunrise and sunset when there is so little solar energy available to fuel this equipment if it is solar-powered might be another question that rises. At night, it is manually maintained in a near vertical position using a self-releasing tie-down so that it may slide down into place and begin tracking when sufficient differential energy is available. Passive trackers are appropriate for simple photovoltaic systems, but not for concentrated photovoltaic systems that require high aiming precision. Actuators composed of shape memory alloys (SMA) have also been utilized instead of gas expansion systems [6].

2.3.3 Comparison between active and Passive solar tracker

In comparison to an active tracker (or any other device), a passive tracker (or any other device) is like a basic individual compared to a knowledgeable technological specialist.

Complexity- The basic passive tracker is made of fewer pieces and has a basic structure. The active tracker is far more complicated, as it requires a power management circuit, sensors, mechanical gears, computer components and electrical motors among other things.

Reliability- There isn’t much that can do wrong with the passive tracker except gas seals. Alloys with shape memory, on the other hand, may help to eliminate this danger. Another dependable alternative are modern active trackers; however, it is reality that component count has an impact on dependability. Complex system reliability necessitates a more precise design and, as a result, a higher price.

Aiming Accuracy- The passive tracker is unable to use very precise positioning sensors that need external power. As a result, passive trackers cannot compete with active trackers in terms of precision. As a result, passive trackers are particularly fit to systems with fewer panels and are incompatible with focused photovoltaic systems.

Monitoring and Alarms- Automatic monitoring and warning systems may be included into powered systems. Passive trackers, on the other hand, are incapable of doing this.

Morning and Evening Performance- When the irradiation is strong enough in the morning, it may take a long time for the passive tracking system to begin to function properly. In a similar manner, as the amount of sunlight available diminishes in the evening, tracking becomes inefficient.

Low Temperatures – Passive trackers may not operate in cold weather.

Wind- Wind loading may be compensated for using active trackers. It's possible that the passive tracker won't work. During wind storms, active systems may be forced to shut down and lock up in a safe condition before automatically resuming normal function. In order for the passive tracker to continue to work, it must first be physically restrained and then released and transported to the proper location.

Cost- The passive tracker is a reasonable price, while the active tracker is significantly more costly. Active trackers (ATs) are solar panels that employ electrical components to guide them toward the sun. These have a distinct edge over PTs in terms of tracking precision. Solar trackers may be divided into two groups depending on how they work: Solar trackers that use astronomical and sensor-based data. Geometric and astronomical formulas, as well as proven geometric and astronomical techniques, are used to calculate the sun's position in astronomical solar trackers. However, in order to change the location's latitude, local date, and time zone, users must be involved via the usage of this monitoring technique. Photo resistor (LDR)-based solar trackers, on the other hand, use light sensors such as photo diodes, solar cells, and pyrometers to follow the sun's movement in real time, while sensor-based solar trackers do not. Because of their simple circuit and inexpensive cost, LDRs are the most often used sensors. Depending on the tracking structure, two or four LDR sensors are used in these systems [6].

2.3.4 Sensor based solar tracker

In dual-axis tracking, four LDRs are employed as a system. They detect the sunlight and provide data to a controller (microcontrollers, PLCs, or other devices), which then uses one or two motors to align the panel perpendicular to the high sunbeams and prevent the panel from being damaged. As the LDR sensor circuit is a voltage divider, it can detect changes in voltage. When the intensity of light shining on an LDR fluctuates, the resistance of the device changes, and as a consequence, the output voltage changes; the change in intensity is translated into a change in voltage. This method is mainly reliant on following a light source, which is accomplished by aligning the PV panel as closely as possible to the direction of the sun's light beams with the use of two servo motors. The motors are controlled by four LDRs mounted at the corners of the four PV panels, which monitor solar incidence. The signal from the LDRs is then processed by the Arduino UNO board's microcontroller, which displays the results. When the analogue data from the LDRs is converted to digital values, the microcontroller outputs two channels, which are used to control the movement of the PV panel, which is controlled by two servo motors. On both vertical and horizontal axes, the rotational movements occur from south to north (elevation tracking) during the seasons and from east to west (azimuth tracking) during the day, on both vertical and horizontal axes [7].

2.4 Single Axis Vs Dual Axis Tracking System

Solar Energy as we all know is a key source of infinite renewable energy which can be used to power most mechanisms in an environment-friendly manner. In order to improve on current solar technology, industries are developing changes to their solar panels in order to provide a greater energy output per unit than earlier and rival models. Solar trackers are a proven method of increasing system output. Unlike fixed tilt ground mount systems, solar trackers cause solar panels to follow the sun's path throughout the day. There are two major types of solar tracker systems available on the market: dual axis and single axis. Dual axis trackers spin on both the X and Y axes, making panels monitor the sun directly. Single axis solar tracker system tracks the sun east to west, revolving on a single point, moving either in unison, per panela row or by section. According to various experts, solar trackers are the new age of solar energy harvesters because of the fact that the increase in the energy yield outweighs the initial extra capital expenditure and leads to overall profit. In the past decade, the cost of solar trackers has reduced drastically due to an increase in demand for this new and advanced technology thereby boosting its production by about 15-30% worldwide [7].

2.4.1 Single axis tracking system

Single-axis solar tracking systems have only been widely used in the solar market quite recently as they function along a singular axis thereby providing a lower energy output in comparison to the dual axis solar tracking systems. However, due to their shorter racking heights, they occupy a smaller area creating a model more suitable for maintenance and functioning.

Single-axis solar trackers are generally classified into two types: centralized single-axis solar trackers and decentralized single-axis solar trackers. Centralized single-axis solar trackers are more common than decentralized single-axis solar trackers. The difference between centralized and decentralized trackers is that centralized trackers utilize a single motor to drive an entire section of panels, while decentralized trackers use a motor for every row of panels, enabling them to track independently of adjacent modules [8].

Although these trackers may seem to be an advanced technology leading to better results, they have their downsides, for instance, sunlight does not reach the earth's surface as direct beams but rather as diffuse light on cloudy days, a single axis solar tracking panel will not be able to accurately track the sun, and the panel will therefore not be able to operate to its full potential. Panels may also drift horizontally in order to catch the diffuse light, which is undesirable.

Hence, modifications are being made to the tracking software of the panels in order to help with tracking in presence of diffuse light, adverse wind conditions and various other environmental factors that could come into play. Newer models are also being developed in order to bear higher wind speeds and adverse climate conditions.

2.4.2 Dual axis tracking system

A dual axis tracker allows your panels to move along two axes, east-west and north-south, using a single tracker. Aiming to collect as much solar energy as possible throughout the year, this system has been designed to maximize efficiency [9]. Additionally, it can monitor seasonal changes in the height of the sun along with normal daily movement.

As a single axis solar tracker can only follow sunlight in one direction, which is elevation movements from east to west, by rotating the structure along the vertical-axis, a dual axis solar tracker can capture the greatest amount of electricity monitoring sunshine in both directions. This device can catch the most amount of sunlight in two movements: azimuth and elevation, and it can also get the greatest amount of light lux all at the same time. Due to the restricted amount of commercial rooftop space available for solar panels, dual-axis trackers, which can generate up to 45 percent more energy than conventional fixed panels, may assist companies in generating enough electricity to run their activities in a little amount of area. Due to the fact that utility-scale installations are usually situated on large plots of land and do not have the tight space restrictions of a commercial roof area, dual-axis configurations are seldom necessary. Consequently, dual-axis trackers are becoming less attractive as a choice for largescale utility-scale projects.

Despite the fact that dual-axis sun trackers are more efficient than single-axis solar trackers, they have a higher level of mechanical complexity, making them more prone to failure. When compared to single-axis solar trackers, they also offer less flexibility and dependability, as well as inconsistent performance in cloudy or gloomy condition [10].

2.4.3 Comparison between single and dual axis solar tracker

Individually adjustable solar trackers feature just one degree of flexibility that acts as the tracker's central axis of rotation. This is often oriented along a North-South axis, although it is feasible to align them along any basic axis as well. In general, single-axis solar trackers are less expensive, more reliable, and have a longer lifetime than dual-axis solar trackers; nevertheless, when compared to dual-axis solar trackers, single-axis solar trackers produce less energy under sunny circumstances and have fewer technical advances.

In contrast to single-axis trackers, dual-axis trackers provide two degrees of freedom, allowing for a much greater range of motion. It is via the cooperation of the main and secondary axes that these trackers can direct the solar panels to particular locations in the sky. When compared to single-axis solar trackers, dual-axis trackers provide a greater degree of versatility as well as more precision in directional aiming, allowing them to be more efficient under sunny circumstances overall [11].

2.5 Effect Of the Dust Density on The Inclination of Solar Panel

In general, the Dhaka city climate is weather: dry, hot and dusty at summer, and moderate temperature, little rain, and dusty at winter and maybe dusty along the year . It is known that the accumulation of dust on the solar panels leads to hide the sun radiation from photovoltaic cells, thus tend to decrease the performance of the system. In order to maintain the operation of the system in optimum level, the dust should be cleaned from time to other, the cleaning process can be carried out easily for small systems, but for the large system it will be too difficult process.

The best way to limit this problem, solar panels should fix with a little inclination, at this position wind and rain can help to remove the most amount of the accumulated dust. According to the above explanation, it recommends to place the solar panels at an inclination angle of about 30o to eliminate the effect of this problem [12].

2.6 Temperature Effect on Solar Panel

Temperature has a significant bad effect on the physical properties of silicon photovoltaic cells in terms of instantaneous energy production, and permanent effect. The permanent effect is the reduction of the solar panel service life, where practical experience has shown a decrease in the energy performance of solar panels by 8% after the first year of operation in Iraqi weather, where the cells expose to more than 100 °C. The instantaneous effect has too much reduction of solar panel performance with temperature rise. It is known that the efficiency of photovoltaic cells decreases with the increase of temperature by about 0.4%/°C [13], at the summer the efficiency of the solar panels reduced significantly to 60% of the design capacity, this amount of redaction is always shown on panel label [14].

Therefore, in Iraq weather at summer days the productivity of solar panels is less than panels productivity at winter, until as know that the intensity of light at summer is greater than at winter, causing a high PV temperature effect.

2.7 Solar Energy Systems

The absorption of solar energy in the photovoltaic cell causes the p-n junction to produce electricity from the DC. The voltage of a single photovoltaic cell is 0.5 volts with low output power, so connecting a number of these cells together will be a system of solar panels of 12 volts or 24 volts. Figure 3 shows the relationship between the electrical voltage and the capacity of the PV panels. There is a peak point in the PV panels called Maximum Power Point (MMP). Connects a controller to the panels and adjusts the voltage and current in a way that achieves the highest performance of the system [15]. There is also a DC-AC adapter that adjusts current and output voltage so that they are within that point. The adapter is called the MPPT, and it is its duty to modify the output voltage of the PV panels. The structure is called the MPPT, which is attached to a series of sub-plates

The photovoltaic system is connected to the national grid using the inverter. The energy generated by the solar cells is known to depend on the amount of solar radiation the panels receive. As mentioned above, the angle of solar radiation falling varies with days and seasons. Therefore, many power plants are using solar tracking devices and adjusting the PV panels to always be perpendicular to the falling solar radiation [16].

Chapter 3

EXPERIMENTAL DESIGN

3.1 Introduction

Light Dependent Resistors are used as the main parts of this system. Resistance of LDR depends on intensity of the light and it varies according to it. The higher is the intensity of light, lower will be the LDR resistance and due to this the output voltage lowers and when the light intensity is low, higher will be the LDR resistance and thus higher output voltage is obtained.

3.2 Experimental Setup and Working Principle

Four LDRs are connected to the Arduino for the dual axis solar tracking system and two LDRs are connected to the Arduino for the single axis tracking system, which serves as the system's input. The LDR's analogue value will be converted to digital using the built-in Analog to Digital Converter. The inputs are analogue LDR values, the controller is Arduino, and the output is a DC motor. If one of the LDRs in a pair receives more light intensity than the other, a variance in node voltages communicated to the respective Arduino channel will occur, allowing the appropriate action to be taken. The solar panel will be moved by the DC motor to the location of the high-intensity LDR that was programmed. The light is detected by the LDR sensor, which delivers a signal to the microcontroller.

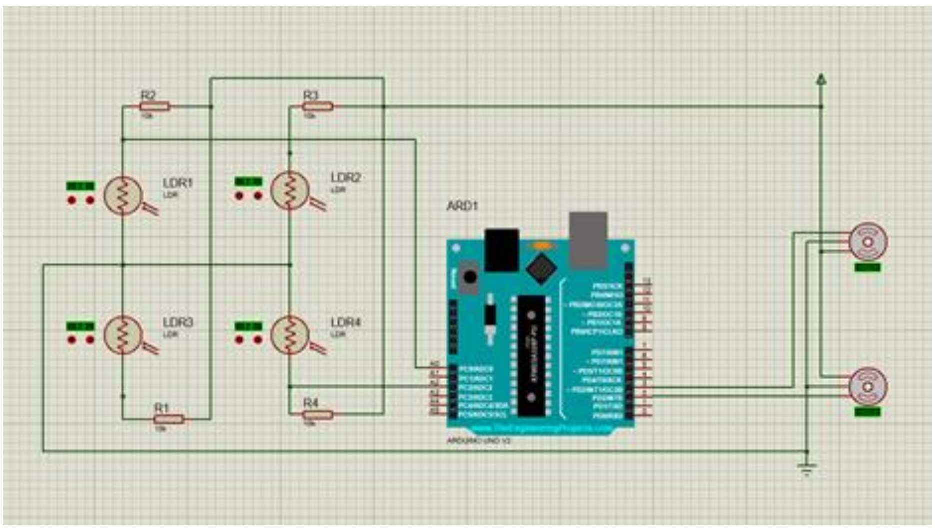

Figure 3.1 Circuit diagram for single axis solar tracking system

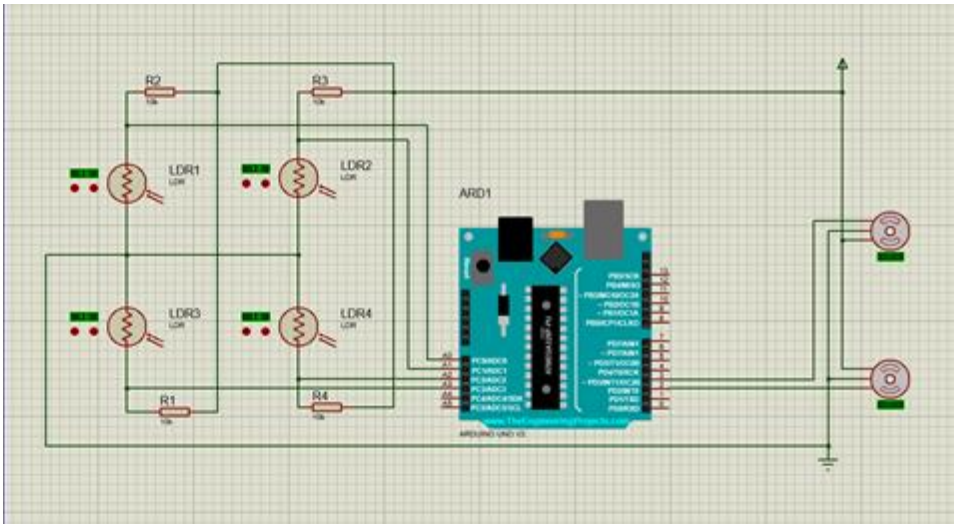

Figure 2.2 Circuit diagram for dual axis solar tracking system

The microcontroller correlates the signals from the LDR sensors and chooses the pivot heading of the DC engine based on more grounded signals. Arduino is a clever device that performs tasks depending on sensor data and initiates engine driving circuits as needed. Assume that the sun changes its region and moves from east to west, causing the light force to differ on one sensor when compared to the other.

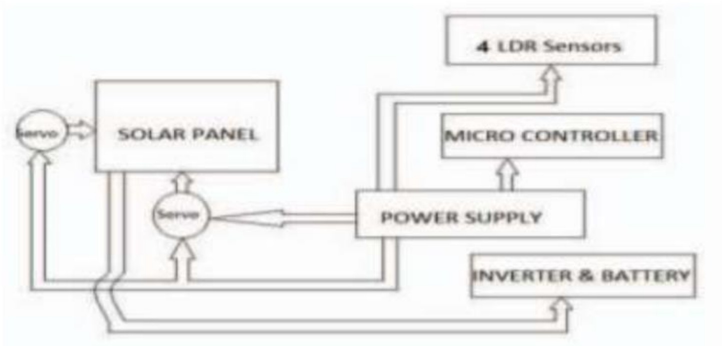

Figure 3.3 Block diagram of the whole system

The controller activates the driver circuit and moves the dc Motors to a new place where the light falling on the sensor sets is the same. A similar method is repeated as the sun's location in the sky changes. As a result, the proposed demonstration can capture more sun rays, and the sun-powered vitality transformation capacity of the frameworks has greatly increased.

3.3 Site Selection

This work was done in Dhaka city (Bangladesh) where the experimental outcomes have been done on 14th of October 2022 which was a sunny day by installing the proposed system devices on the roof of building. The time for collection of data power output between 7:00 a.m. to 5:00 p.m.

Figure 3.4 Site location of the experiment mentioning Dhaka, Bangladesh

3.4 Hardwires and Software

The description of Hardwires and softwires used in this project are given below:

3.4.1 Solar panel

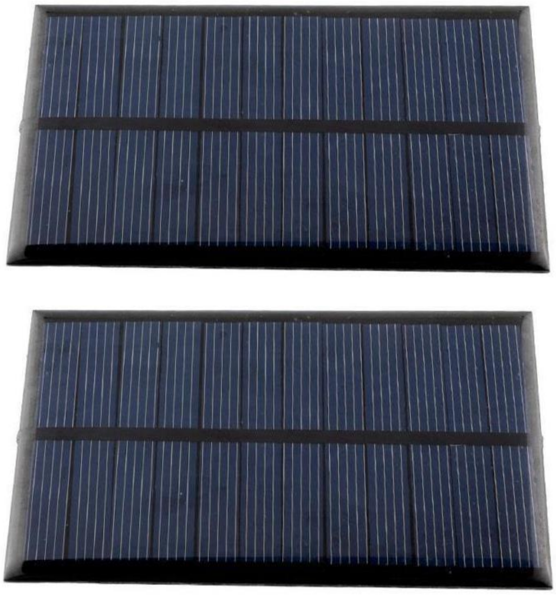

Figure 3.5 Solar panel

Solar energy is a group of photovoltaic cells that produce electrical energy from sun light energy and convert the received light energy from sun into electrical energy (Jamroen *et al.*, 2020). Solar panel extracts high-energy emitted from the sun. They are widely applications of solar panel in industrial area, domestic and street lights.

There are many types of solar panel distinguished by their efficiency, price and temperature coefficient, that are available in the market. Some of them are monocrystalline, polycrystalline and thin film. The polycrystalline (6V 1W 69*100mm) Mini Solar Panel type of solar panel was selected for this project.

3.4.2 Sensing unit

In most solar tracking systems, there are several types of light sensors. Light Dependent Resistor (LDR) is one of these light sensors. Where the LDR sensor can be defined as a sensor to light that is coming from the sun along the day by receiving sunlight and giving a numerical value to the controller to direct the solar panels in a direction where the solar radiation has its maximum capacity [17]. Thus, LDR has a significant role

Figure 3.6 Light dependent resistor

in increasing the amount of solar energy extracted from solar panels. Four LDR-type sensors were used in this project, two for vertical movement and two for horizontal movement in order to increase efficiency in solar energy. The controller will receive four numerical values from the four LDR sensors and then compare these four values to determine which values are the highest and then directs one of the Motors either horizontally or vertically to move the solar panels to the location where the highest value was detected in order to absorb the largest Quantity of solar energy.

3.4.3 1k ohm resistors

These are resistors with a resistance model of 1KΩ Ohm, the voltage of 1/2 Watt & tolerance of ±5%. Excellent Reliable Performance, Humidity Resistance. Wide Applications in Telecommunication, Computers, Industrial Control, Data Processing, Etc.

Figure 3.7 1k ohm register

3.4.4 Microcontroller unit / Arduino UNO

In our project, we proposed Arduino based dual axis solar tracker. Arduino board unit controls the movement of solar panel that rotates and traces the direction of sun. Arduino board uses variety of microcontrollers and controllers. It is equipped with both analog and digital input/output. It has 14 digital input/output pins (of which six is used as PWM output), six analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack and a reset button is used. The input command was given to the Arduino using Integrated Development Environment platform. The Arduino Uno differs from all preceding boards because it does not use the FTDI USB-to-serial driver chip. Instead, it features the ATmega8U2 programmed as a USB-to-serial converter.

Figure 3.8 Arduino UNO

3.4.5 Servo motor (mini servo sg90)

Servo motor (MINI SERVO SG90) is one of the various types of DC motor available in electronic application. This type of motor requires Operating voltage: 3.0V~7.2V. This motor consists of three wires namely signal, positive and ground wire. It also comprises several parts which are the motor and gearbox, position sensor, an error amplifier, motor driver and a circuit to decode the requested position. Servo motor only

Figure 3.9 Mini servo motor

rotates by the maximum of 180 degrees. PWM is used to control the motor. PWM analog signal will go through an electronic circuit and convert the analog signal into a digital signal. PWM in servos is used to control the direction and position of the motor. There were two servo motors used in this project for horizontal and vertical axis respectively.

3.4.6 Controller

12V/24V Adjustable LCD Display Solar Panel Battery Regulator with USB Port Auto PWM

Figure 3.10 Solar Controller

Controllers Intelligent System Charging Controller has been selected for its advanced facility, represented as saving data of battery voltage, current of battery charging and discharging and the total amount of solar power.

3.4.7 12v lead acid battery

A battery is a device consisting of one or more electrochemical cells with external connections for powering electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. Here 12v lead acid battery is used for its various advantages and recommended in principle for applications such as: electric scales, cars or electric toys for children. Accumulators of this type use VRLA (Valve-Regulated Lead-acid battery) technology, are hermetically sealed and can be mounted

Figure 3.11 12v lead acid battery

in any position without the risk of acid leakage. The battery terminals are attached with shoes instead of screws. They are resistant to cyclic discharges, i.e., to frequent discharge-charge cycles.

3.4.8 Multimeter

Figure 3.12 Multimeter

A multimeter is a measuring instrument that can measure multiple electrical properties. A typical multimeter can measure voltage, resistance, and current, in which case it is also known as a volt-ohm-milliammeter (VOM), as the unit is equipped with voltmeter, ammeter, and ohmmeter functionality, or volt-ohmmeter for short. Some feature the measurement of additional properties such as temperature and capacitance.

3.4.9 Software

The Arduino Programming Language, or Arduino Language, is a native language supported by Arduino. This language is based on the Wiring development platform, The Arduino IDE is based on the Processing IDE, which in turn is based on the Wiring IDE. We commonly utilize the Arduino IDE a when working with Arduino. The Arduino IDE is a piece of software accessible for all main desktop a platform

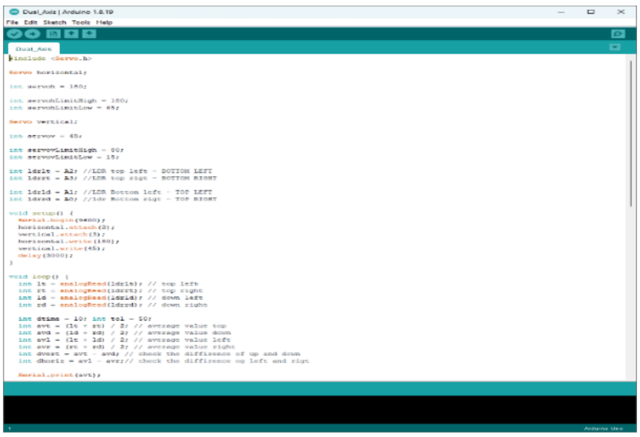

Figure 3.13 Programming in Arduino IDE

(Windows, macOS, and Linux) that provides us with two things: a programming editor with built-in libraries and a means to quickly build and load our Arduino programs onto a computer-connected board.

The Arduino Programming Language is essentially a C++a based framework. The sketch is the term for a program created in the Arduino Programming a Language. Normally, a sketch is stored with the uno extension (from Arduino). The key difference between this and “normal” C or C++a is that all of your code is wrapped in two primary functions.

Chapter 4

DATA COLLECTION, ANALYSIS AND DISCUSSION

4.1 Introduction

The rapid increase in energy demand cannot be resolved easily until there is an alternative way to meet the demand. So, the user will become less compulsive on the convenient fossil fuel energy. The stored energy also plays a significant role to avoid the imbalance of the power system. With the transition away from conventional fossil-fuel-based energy sources, a variety of solar energy supplies are now available [18]. Solar energy is one of the utmost major attempts to address the problem of global warming, as well as a source of renewable energy. Additionally, to being a cost-effective source of energy, it may assist in providing a substitute to conventional fossil-fuel-based energy a resource. Consumption is actually contained within photovoltaic and thermal energy, necessitating the employment of solar tracking panels.

4.2 Data Collection

This section presents and discuss the performance of different tracking system and proposed system with respect to different time period in a day.

Table 4. 1 Data obtained from fixed solar tracking system on 14th of October 2022

Time	Current (A)	Voltage (V)	Power (W)
7:00	0.07	3.5	0.245
8:00	0.21	5.23	1.0983
9:00	0.47	10.86	5.1042
10:00	0.89	14.73	13.1097
11:00	1.29	16.89	21.7881
12:00	1.42	18.17	25.8014
13:00	1.58	18.85	29.783
14:00	1.33	18.05	24.0065
15:00	1.18	15.38	18.1484
16:00	0.75	11.62	8.715
17:00	0.59	6.86	4.0474

Table 4.2 Data obtained from single axis solar tracking System on 14th of October 2022

Time	Current (A)	Voltage (V)	Power (W)
7:00	0.79	7.98	6.3042
8:00	1.19	10.17	12.1023
9:00	1.41	13.96	19.6836
10:00	1.46	16.14	23.5644
11:00	1.48	17.18	25.43
12:00	1.59	18.11	28.7949
13:00	1.73	18.43	31.88
14:00	1.49	17.06	25.4194
15:00	1.26	15.3	19.27
16:00	1.09	14.23	15.5107
17:00	0.71	11.87	8.4277

Table 4. 3 Data obtained from dual axis solar tracking system on 14th of October 2022

Time	Current (A)	Voltage (V)	Power (W)
7:00	0.96	8.22	7.8912
8:00	1.29	10.67	13.7643
9:00	1.47	14.13	20.7711
10:00	1.52	16.92	25.7184
11:00	1.68	17.48	29.3664
12:00	1.77	18.76	33.2052
13:00	1.89	18.97	35.8533
14:00	1.53	18.65	28.5345
15:00	1.34	15.22	20.3948
16:00	1.12	14.76	16.5312
17:00	0.73	12.58	9.1834

The powers tracking of solar panel with different positions are tabulated above in table 4.1, 4.2, and 4.3. It is clearly evident that the proposed dual axis tracker perfectly aligns with the sun direction and tracks the sun movement in a more efficient way and has a tremendous performance improvement. The experimental results clearly show that dual axis tracker is superior to single axis tracker and fixed systems. Power Captured by dual axis solar tracker is high during the whole observation time period and it maximizes the conversion of solar irradiance into electrical energy output. As a result, it creates a solution for effective utilization of solar energy.

4.3 Data Analysis

The powers tracking of solar panel with different positions are tabulated above in data collection section. It is clearly evident that the proposed dual axis tracker perfectly aligns with the sun direction and tracks the sun movement in a more efficient way and has a tremendous performance improvement. The experimental results clearly show that dual axis tracker is superior to single axis tracker and fixed systems. Power Captured by dual axis solar tracker is high during the whole observation time period and it maximizes the conversion of solar irradiance into electrical energy output is shown in the table 4.1, 4.2, and 4.3. As a result, it creates a solution for effective utilization of solar energy and thus helps in creating smart houses. The bar chart comparison of the result of the study are given below.

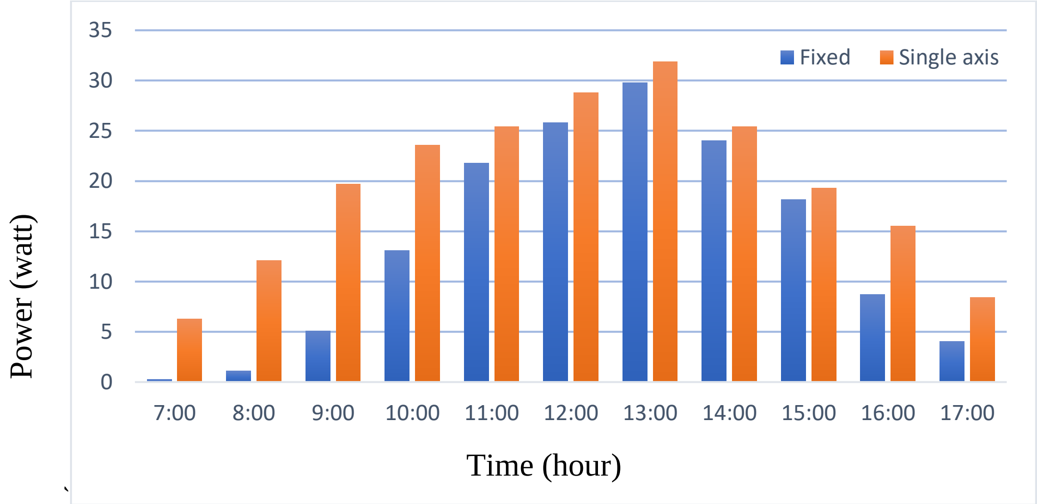

Figure 4.1 Comparison between fixed vs single axis solar tracking system

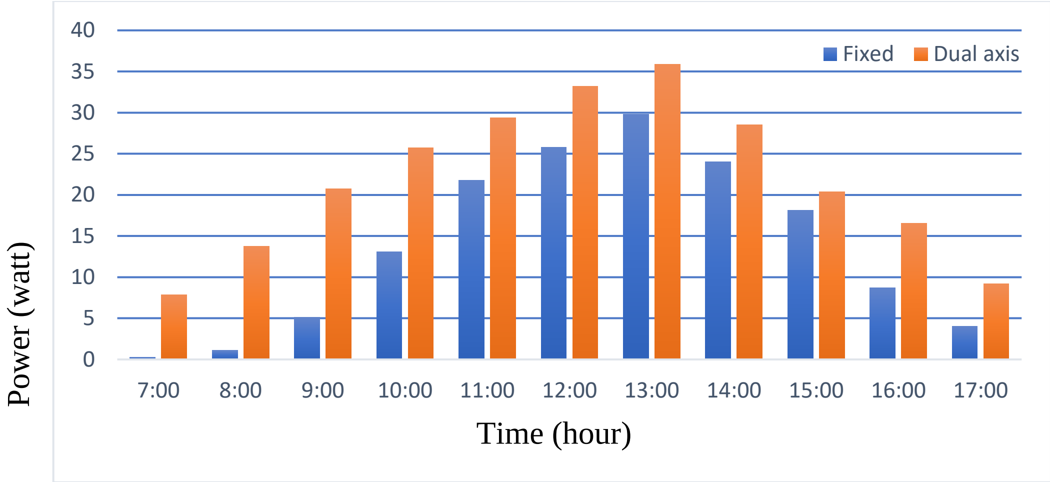

Figure 4.2 Comparison between fixed vs dual axis solar tracking system

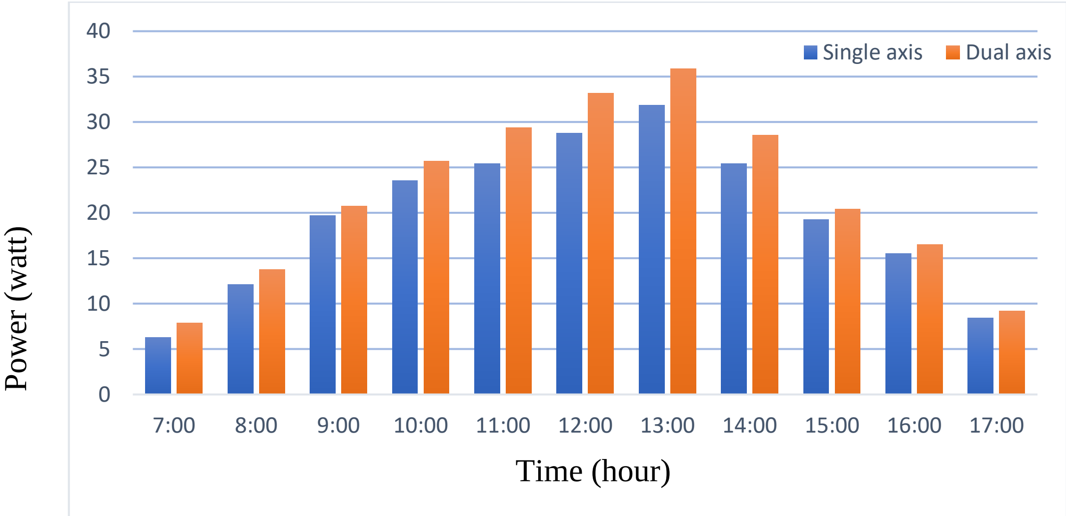

Figure 4.3 Comparison between single axis vs dual axis solar tracking system

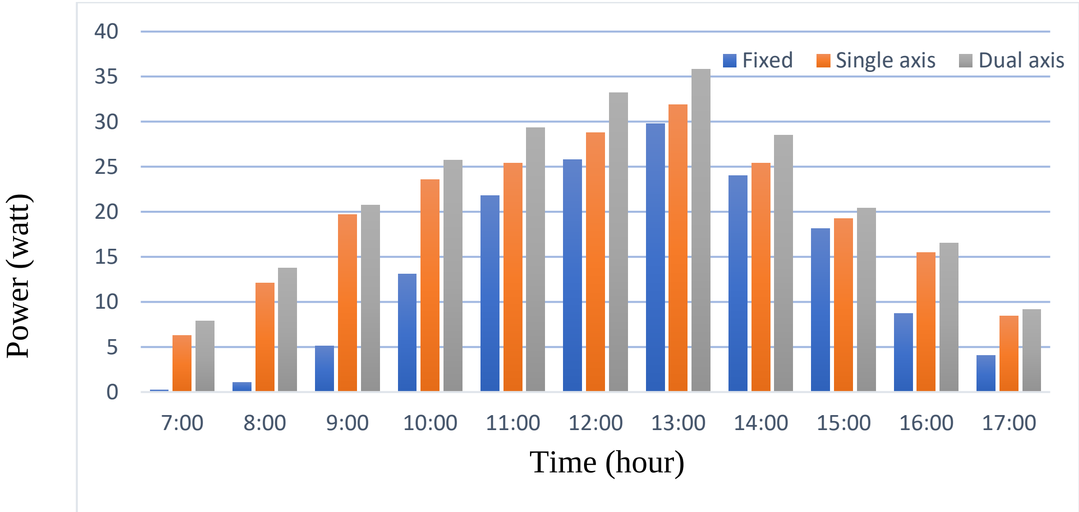

Figure 4.4 Comparison between fixed, single axis and dual axis solar tracking system

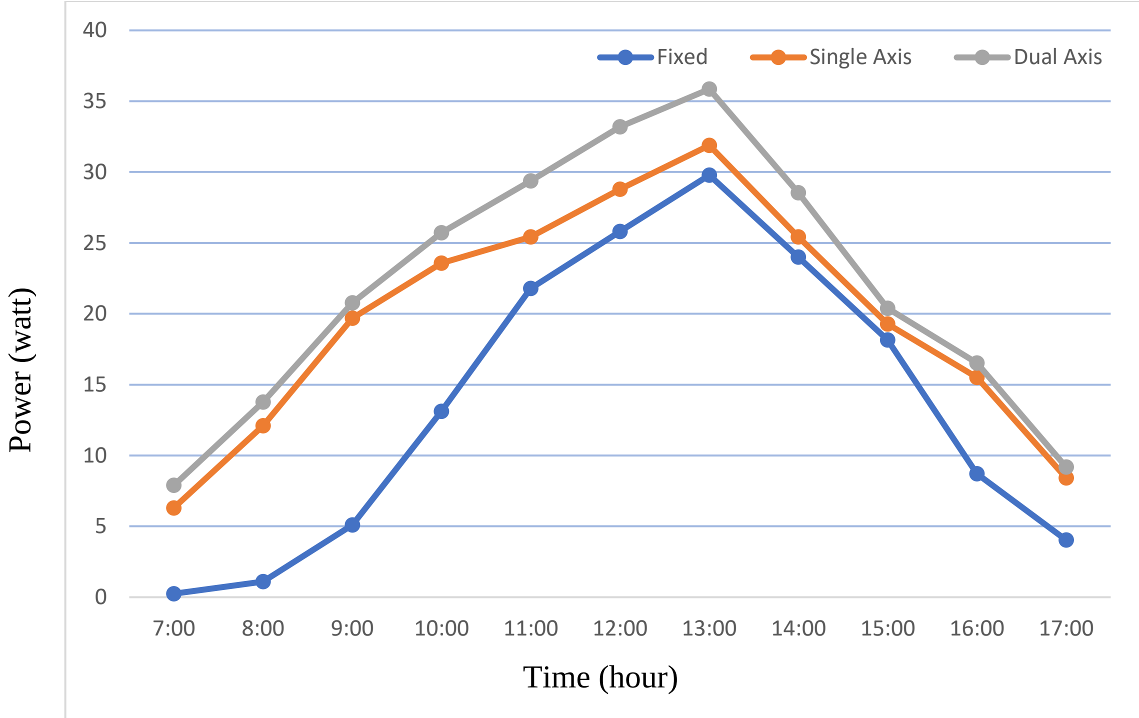

Figure 4.5 Comparison between fixed, single axis, dual axis solar tracking system

Bar chart comparison of solar power between different tracking methods is shown above figure. 4.1, 4.2, 4.3, 4.4 and 4.5. It is clearly showing that proposed method yields better output power compared to existing method in a day compared with the existing system and efficiency of solar panel is effectively improved.

4.4 Efficiency Measurement of the System

Efficiency is measured by the comparison of power generated by tracked and stationary solar panels. Mathematically efficiency is the percentage of the ratios of output power into the input power. In this case, power generated by the tracking system was considered as the reference to measure the efficiency. The graph in Figure 16 was used to compare the power generated by each solar system. The tracked solar system has improved the efficiency of solar panel.

It is mathematical expressed as:

$$\text{Efficiency} = \frac{(\mathbf{P}tracked - \mathbf{P}stationary)}{\mathbf{P}tracked} \times 100\ \%$$

Efficiency of single axis solar tracking system to the fixed solar system pointing to the Figure. 4.1:

$$\text{Efficiency} = \frac{(\mathbf{P}tracked - \boldsymbol{P}stationary)}{\mathbf{P}tracked} \times 100$$

$$\text{Efficiency} = \frac{(\mathbf{216.4 - 151.84})}{\mathbf{216.4}} \times 100$$

Efficiency = 29.83 %

Efficiency of dual axis solar tracking system to the fixed solar system pointing to the Figure. 4.2:

$$\text{Efficiency} = \frac{(\mathbf{P}tracked - \boldsymbol{P}stationary)}{\mathbf{P}tracked} \times 100$$

$$\text{Efficiency} = \frac{(\mathbf{241.21 - 151.84})}{\mathbf{241.21}} \times 100$$

Efficiency = 37.05%

Improvement of efficiency of dual axis solar tracking system to the single axis solar tracking system pointing to the Figure. 4.3:

Efficiency = 37.05% — 29.83 %

= 7.22%

Efficiency of single axis and dual axis solar tracking systems are showing below:

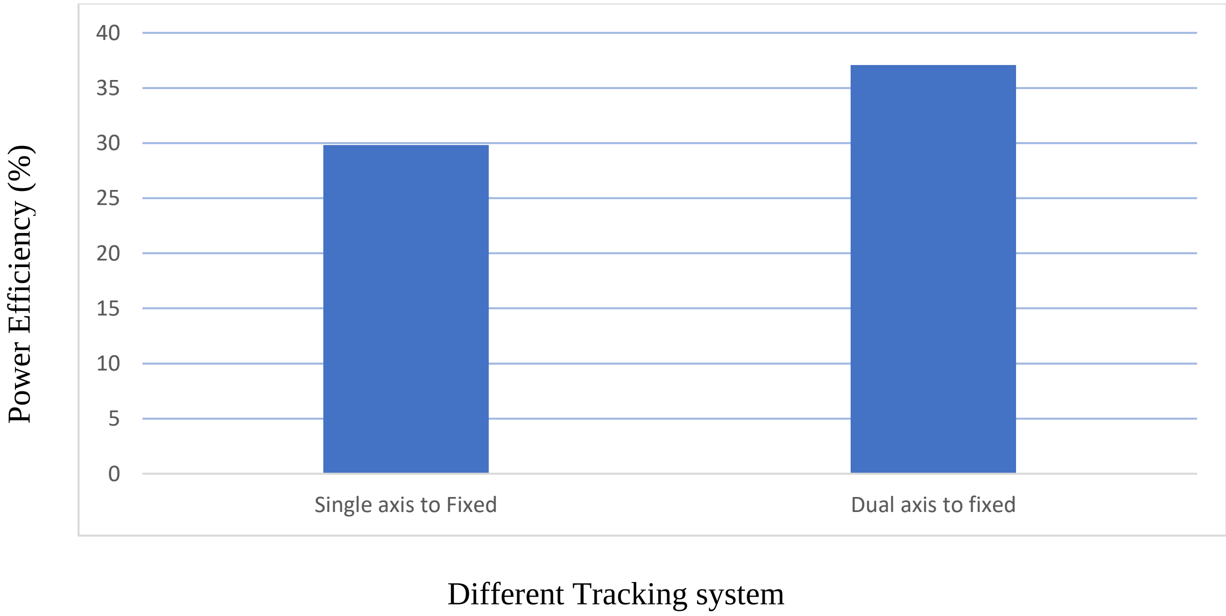

Figure 4.6 Efficiency curve of Single and Dual axis Solar tracking system

Chapter 5

CONCLUSIONS AND RECOMMENDATION

5.1 Summary

The Arduino based multi axis solar tracking based solar panel is designed and successfully implemented to increase the efficiency of solar panel. The proposed dual axis solar tracker is more effective than the existing single axis solar tracker and fixed mount. The proposed solar tracker which automatically tracks the sun to grab maximum solar power with the help of Arduino board was effectively achieved. The implementation cost of Arduino board for tracking solar power is low and it is implementation is simple.

This paper included a practical work compare the performance of different photovoltaic systems; the solar tracker system was installed in Dhaka-Bangladesh to measure the solar radiation received. The impact of the use of single axis and double axis trackers and compared this influence to fixed solar panel, a solar tracker had been constructed, the three system were tested and got a logical knowledge. The influence of each device on solar energy systems were, the single axis tracker system tends to 29.83% Improvement of power generated relative to the fixed solar panel; the dual axis tracker system tends to 37.05% Improvement of power generated relative to the fixed solar panel while double axis tracker system tends to 7.7% rise compare to the fixed solar panel.

Finally, this project successfully enhances the potential of a stationary solar panel by effectively implementing a tracker using LDRs and Arduino Uno which is a coherent method of increasing efficacy and solar power generation. The main destination of this project is to achieve the highest performance of a Multi axis solar tracking system. With the available resources and time, the objective of the project was met.

5.2 Recommendation

The following are a few suggestions that may be incorporated in the future to improve the model:

- In the future, more efficient sensors that are both cost effective and use minimal power may be considered for future projects. This would improve efficiency.

- A polycrystalline solar panel is utilized in this model; however, for greater energy output, the model may be equipped with monocrystalline solar panels, which are more efficient when production scale exceeds 1KW.
- Use higher motors with greater torque values for larger panels, which helps produce a higher solar energy output.
- As sensor-based tracking can have limitations such as dust and clouds obstructing the sunlight.

In this project, we have worked on different sun angles and mainly the solar radiation for different systems. We have ignored different factors like humidity, sun intensity etc. So, here is a scope to improve it more and make it more accurate.

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APPENDIX-A

Programing Code of Single Axis Solar Tracking System

```
#include <Servo.h>

#define min_limit    40

#define max_limit   160

#define threshold     5

#define ldr_top A2 // LDR TOP Right Pin

#define ldr_bot A0  // LDR Bottom Right Pin

int ldrtop, ldrbot;

int diff, angle = 90;

Servo servo;

Servo servo2;

void setup() {

  Serial.begin(9600);

  delay(10);

  servo.attach(2);

  servo.write(angle);

  servo2.attach(3);

  servo2.write(angle);

}

void loop() {

  ldrtop = analogRead(ldr_top);

  ldrbot = analogRead(ldr_bot);

  serialPrint();
```

```
  ldrtop = map(ldrtop, 0, 1023, 0, 99);
  ldrbot = map(ldrbot, 0, 1023, 0, 99);
  diff = abs(ldrtop - ldrbot);
  if (diff > threshold) {
    if (ldrtop > ldrbot) {
      angle++;
      if (angle > max_limit) angle = max_limit;
      servo.write(angle);
      delay(10);
    }
    else {
      angle--;
      if (angle < min_limit) angle = min_limit;
      servo.write(angle);
      delay(10);
    }
  }
}
void serialPrint() {
  Serial.println((String) "diff:" + diff + " "
                 + "LDRTOP:" + ldrtop + " "
                 + "LDRBOT:" + ldrbot);
}
```

APPENDIX-B

Programing Code of Dual Axis Solar Tracking System

```
#include <Servo.h>

Servo horizontal;

int servoh = 180;

int servohLimitHigh = 180;

int servohLimitLow = 65;

Servo vertical;

int servov = 45;

int servovLimitHigh = 80;

int servovLimitLow = 15;

int ldrlt = A2; //LDR top left - BOTTOM LEFT

int ldrrt = A3; //LDR top rigt - BOTTOM RIGHT

int ldrld = A1; //LDR Bottom left - TOP LEFT

int ldrrd = A0; //ldr Bottom rigt - TOP RIGHT

void setup() {

  Serial.begin(9600);

  horizontal.attach(2);

  vertical.attach(3);

  horizontal.write(180);

  vertical.write(45);

  delay(3000);

}

void loop() {
```

```
int lt = analogRead(ldrlt); // top left
int rt = analogRead(ldrrt); // top right
int ld = analogRead(ldrld); // down left
int rd = analogRead(ldrrd); // down right
int dtime = 10; int tol = 50;
int avt = (lt + rt) / 2; // average value top
int avd = (ld + rd) / 2; // average value down
int avl = (lt + ld) / 2; // average value left
int avr = (rt + rd) / 2; // average value right
int dvert = avt - avd; // check the diffirence of up and down
int dhoriz = avl - avr;// check the diffirence og left and rigt
Serial.print(avt);
Serial.print(" ");
Serial.print(avd);
Serial.print(" ");
Serial.print(avl);
Serial.print(" ");
Serial.print(avr);
Serial.print(" ");
Serial.print(dtime);
Serial.print(" ");
Serial.print(tol);
Serial.println(" ");
if (-1 * tol > dvert || dvert > tol) {
```

```
  if (avt > avd)
  {
    servov = ++servov;
    if (servov > servovLimitHigh)
    {
      servov = servovLimitHigh;
    }
  }
  else if (avt < avd) {
    servov = --servov;
    if (servov < servovLimitLow)
    {
      servov = servovLimitLow;
    }
  }
  vertical.write(servov);
}
if (-1 * tol > dhoriz || dhoriz > tol) {
  if (avl > avr)
  {
    servoh = --servoh;
    if (servoh < servohLimitLow)
    {
      servoh = servohLimitLow;
```

```
      }
    }
    else if (avl < avr)
    {
      servoh = ++servoh;
      if (servoh > servohLimitHigh)
      {
        servoh = servohLimitHigh;
      }
    }
    else if (avl = avr) {
    }
    horizontal.write(servoh);
  }
  delay(dtime);
}
```