Faculty of Electronic and Computer Technology and Engineering

DEVELOPMENT OF IOT BASED SMART SOLAR TRACKING SYSTEM FOR OPTIMAL POWER GENERATION USING NODEMCU AND BLYNK APPLICATION

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Bachelor of Electronics Engineering Technology with Honours

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ABSTRACT

This project aims to develop an IoT-based smart solar tracking system utilizing NodeMCU and the Blynk application, which is designed to optimize power generation from solar panels by continuously adjusting their position based on real-time data obtained from light sensors. By integrating ESP32 as the control unit, the system enables automated movement of the solar panels through a motorized mechanism, ensuring their optimal alignment with the sun. The Blynk application facilitates remote monitoring and control, allowing users to access the system's performance data, receive real-time information on energy generation, and remotely manage the solar tracking system. This comprehensive solution not only enhances the efficiency of solar energy generation but also reduces the need for manual intervention, while providing a user-friendly interface for remote access and control.

ABSTRAK

Projek ini bertujuan untuk membangunkan sistem penjejakan solar berasaskan IoT menggunakan NodeMCU dan aplikasi Blynk, yang direka untuk mengoptimumkan penjanaan kuasa daripada panel solar dengan melaraskan kedudukannya secara berterusan berdasarkan data masa nyata yang diperoleh daripada penderia cahaya. Dengan menggunakan ESP32 sebagai unit kawalan, sistem ini membolehkan pergerakan automatik panel solar melalui mekanisme bermotor, memastikan penjajaran optimumnya dengan matahari. Aplikasi Blynk memudahkan pemantauan dan kawalan jauh, membolehkan pengguna mengakses data prestasi sistem, menerima maklumat masa nyata tentang penjanaan tenaga, dan mengurus sistem pengesan solar dari jauh. Penyelesaian komprehensif ini bukan sahaja meningkatkan kecekapan penjanaan tenaga suria tetapi juga mengurangkan keperluan untuk pengawalan manual, sambil memberikan pengguna untuk mengakses sistem dari jauh.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter provides a concise overview of the project's concept, including a brief introduction to its background, the identified problems that sparked the project idea, the objectives to be accomplished, the scope of the project, and the anticipated outcomes.

1.2 Background

The solar panel industry has experienced significant growth and improvement over the years. Initially developed in the 1950s, solar panels were primarily used in space exploration and satellite technology. However, with the increasing concern for environmental sustainability and the need for clean energy sources, solar panels found their way into mainstream applications.

In the early stages, solar panels were expensive and had limited efficiency, making them less accessible to the general public. However, advancements in technology and manufacturing processes have led to substantial improvements in the industry. The efficiency of solar panels has increased steadily, allowing for greater energy conversion from sunlight into electricity. This improvement has made solar energy a viable and cost-effective alternative to traditional fossil fuels.

In recent years, the integration of smart technologies and energy storage solutions has also been a crucial development in the solar panel industry. Battery storage systems allow for the storage of excess energy generated during peak sunlight hours, which can be used during periods of low solar irradiation or at night. This capability has increased the reliability and usability of solar power systems, making them more attractive to consumers and businesses.

The solar panel industry has undergone significant improvements over time, and the integration of IoT technology has played a crucial role in enhancing their efficiency and functionality. With IoT-enabled solar panels, monitoring, maintenance, energy management, and grid integration have become more efficient and intelligent, paving the way for a sustainable and interconnected energy future.

1.3 Problem Statement

The ineffective use of solar energy caused by static solar panels that are unable to modify their position to follow the movement of the sun is the issue statement of the development of an IoT-based smart solar tracking system for optimal power generation utilising the Blynk application.

Since solar panels are typically fixed in place, they do not always face the sun at the best angle for maximum power production. An enormous amount of energy is squandered as a result, particularly in the early morning and late afternoon when the sun is not directly overhead.

The project intends to create an intelligent solar tracking system that can move the solar panels to follow the path of the sun throughout the day in order to solve this issue. The system is an excellent option for locations where access to the system is difficult or remote since it makes use of IoT technology and the Blynk application to allow remote monitoring and control.

The creation of this sophisticated solar tracking system contribute to improving solar energy utilisation effectiveness and minimising energy lost as a result of solar panel orientation that is static. Since solar energy is a major source of renewable energy, increasing its effectiveness helps to lessen reliance on fossil fuels and mitigate the effects of climate change. This will have significant economic and environmental advantages.

1.4 Project Objective

The objective of this project is to develop a smart solar tracking system that enhances the efficiency and effectiveness of solar panel installations. By accurately tracking the movement of the sun throughout the day, the system ensure that solar panels are always aligned with the sun's position, maximizing the absorption of solar energy and increasing power generation. This objective aims to achieve the following goals:

a) Design and build a system for tracking the sun movement that is able to move solar panels position depends on the sun's course.

b) Use IoT technology and the Blynk app to monitor and control the solar tracking system from afar. This will make it easy to use and manage.
c) Develop a smart solar tracking system with optimal power generation, which will not only maximize the efficiency of solar panels but also contribute to a sustainable and eco-friendly energy solution.
d) Proving the efficiency of smart solar tracking system compare to static solar panel.

1.5 Scope of Project

The design and implementation of a solar tracking system using an ESP32 board, servo motors, and sun-tracking devices allow for the efficient utilization of solar energy. By continuously aligning the solar panels with the sun's position throughout the day, the system can maximizes power generation. This setup ensures that the solar panels are always perpendicular to the sun's rays, optimizing the amount of sunlight received.

The system integrates with IoT technology and the Blynk app tp provides remote monitoring and control capabilities for the solar tracking system. Users can access the system's data and control its operation from a distance using their smartphones or other devices. This functionality allows for real-time tracking updates, performance monitoring, and the ability to adjust settings as needed.

Comparing the solar tracking system's power production a standard static solar panel reveals the benefits of utilizing sun-tracking technology. The solar tracking system has a big advantage in terms of power output since it actively follows the sun's path. By adapting to the sun's position throughout the day, it captures a larger amount of sunlight, resulting in higher energy production compared to a fixed solar panel that remains in a fixed position.

In addition to its power-generation capabilities, the solar tracking system can also incorporate features to notify or alert relevant authorities about its status and battery charging percentage. This functionality ensures that any issues or maintenance requirements are alerted early. By sending notifications or alerts, the system can inform authorities, such as power malfunctions or low battery levels, allowing for troubleshooting.

The combination of ESP32 based solar tracking technology, IoT integration, and monitoring through the Blynk app offers an efficient and effective solution for maximizing solar energy generation. The system's ability to track the sun optimally positions the solar panels, resulting in increased power output compared to static solar panels. The remote monitoring and alert features enable proactive maintenance and intervention, ensuring smooth operation and uninterrupted power generation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter explore prior research and relevant works that have been conducted in relation to the proposed project. This encompasses a comprehensive literature review, involving the study, evaluation, and analysis of various sources such as journals, theses, articles, and research papers. By reviewing existing works, significant data and information can be gathered from related projects, which contribute to the advancement and success of the project.

2.2 Past Related Works

This related works section of a research paper on the development of IoT based smart solar tracking system for optimal power generation using NodeMCU and Blynk application would discuss existing studies and projects that have explored similar topics or utilized similar technologies. It aims to provide an overview of the current state of research in the field and highlight the gaps or limitations that the proposed study aims to address.

2.2.1 Microcontroller-Based Two-Axis Solar Tracking System

The purpose of this project is to design and implement a two-axis solar tracking system prototype utilising a PIC microcontroller. A parabolic reflector or dish is used by the system to absorb solar energy and produce high temperatures. The control system interfaces with the solar tracking system using the assembly programming language and is based on a PIC 16F84A microcontroller. Two 12V, 6W DC gear box motors are used to regulate the motion of the reflector, and light dependent resistors (LDR) are used to follow the sun's movement. To achieve precise movement, the mechanical design features well considered gear ratios. To enable tracking and system operation, the control system is made up of a number of parts, including TA7291PICs, PIC16F84A microcontrollers, and LM358 window comparators.

The hardware implementation involves constructing the parabolic reflector using a glass fiber plate and ensuring its accurate shape. The focus of the reflector is tested using a laser pointer to verify its parabolic shape and determine the usable frequency range. The gear box system is designed using worm and worm wheel DC gear box motors, along with helical gears for vertical and horizontal motion of the reflector. The gear ratios are carefully chosen to achieve the desired speed and motion. The control system components, such as LDRs and LM358 comparators, are used to detect the position of the reflector and interface with the PIC microcontroller.

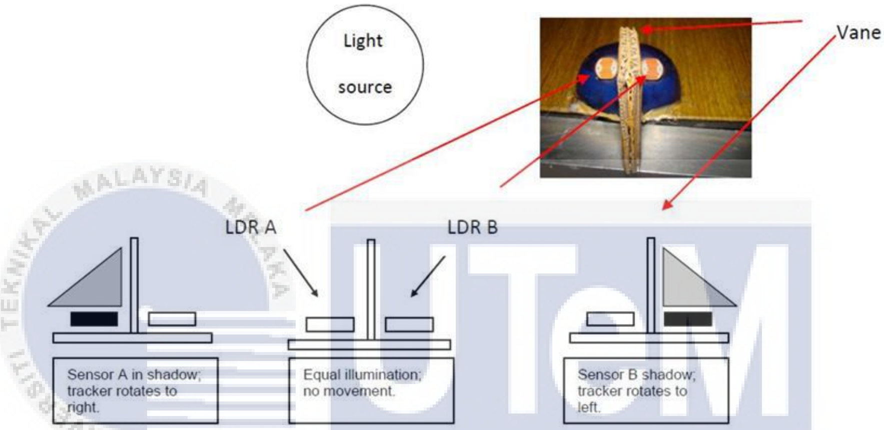

Figure 2.1 : Operation of LDR sensors

Assembly programming language is used to implement the control system's software. The programme enables effective motor control by including time delays for motor stepping. Inputs from the sensors are sensed by the PIC16F84A microcontroller, which then regulates the movement of the reflector as necessary. Throughout the day, the tracking system is intended to follow the sun's course until the reflector hits the limit switches. The project showcases the use of a two-axis solar tracking system with a PIC microcontroller and focuses on precisely tracking the sun to maximise solar energy gathering using a parabolic reflector.

2.2.2 A Low Cost Single-Axis Sun Tracker System using PIC Microcontroller

The study describes a low-cost PIC microcontroller-based single-axis sun tracker system. The device tracks the path of the sun to increase the effectiveness of solar panel systems. The system moves the solar panel using a geared motor that is managed by a PIC16F84A microprocessor. The microprocessor compares the resistance of the sensors to estimate the position of the sun after photocells are used to detect sunlight.

The technology is automated, economical, and capable of accurate solar tracking. It makes use of an LDR as a sensor to determine the brightness of the light. The LDR's resistance fluctuates according on how much light it gets. The microcontroller can identify if the solar panel is appropriately oriented with the sun by comparing the resistance of two LDR sensors. The microprocessor triggers the motor to move the solar panel such that both sensors receive an equal amount of light if one sensor is in the shade.

The PIC16F84A microcontroller, which has programmable features and has control over the motor and sensors, is incorporated into the system. Both the microcontroller architecture and the PicBasic programming procedure are discussed. The microcontroller, sensors, a clock oscillator, voltage regulation hardware, and an H-bridge motor driver are all components of the controller board. A base platform with wheels and a geared motor are part of the mechanical design of the system to move the solar panel.

In summary, this work provides a single-axis sun tracker system that is both affordable and uses a PIC microcontroller. The method moves the solar panel into position according to the movement of the sun using photocells and a geared motor. It provides automated tracking, dependable operation, and effective energy output. The system's components, including the microcontroller, sensors, software, and mechanical design, are covered in great detail in the paper.

2.2.3 Solar Tracking System using Microcontroller

The construction of a solar tracking system created with a microcontroller is covered in the paper titled "Solar Tracking System using Microcontroller" by Priyanjan Sharma and Nitesh Malhotri, given at the 2014 1st International Conference on Non Conventional Energy (ICONCE 2014). The device actively tracks the sun's path to maximise energy production from solar panels. To detect sunlight and alter the solar panel's position accordingly, the system uses light-dependent resistors (LDRs) on the panel. The relevance of renewable energy sources is emphasised in the article, and the potential of solar energy as a different form of energy is highlighted.

According to the authors, solar energy technology could help with the problems of rising energy prices, dwindling fossil fuel supply, and environmental concerns. They point out that the total quantity of energy obtained from non-renewable resources is far outweighed by the solar energy that reaches the Earth's surface. The article suggests using a solar tracking device to effectively harness solar energy. The technology tries to maximise the amount of power absorbed by the photovoltaic (PV) systems by continuously shifting the position of the solar panel to face the sun.

The controller and parts of the system are described in the paper. A microcontroller (AT89S52) serves as the primary element in the hardware design, together with light-dependent resistors (LDRs) for sunlight detection, a stepper motor for moving the panel, and a voltage regulator for a steady power supply. Based on the inputs from the LDRs, the microcontroller is programmed to regulate the rotation of the solar panel. The software architecture and microcontroller operation are depicted in a flow chart by the authors. The testing results show that, with an estimated 13% increase in power efficiency, the single-axis solar panel tracking system generates more power compared to fixed solar panels.

In conclusion, the research proposes a solar tracking system that makes use of a microcontroller and light-dependent resistors to enhance solar panel energy output. The system tries to utilise solar energy as a renewable energy source as efficiently as possible. Comparing the testing results to fixed solar panels, improved power generation is evident. The suggested system responds to the rising need for alternative energy sources as well as the development of sustainable energy solutions.

2.2.4 Design, Modeling and Testing of a Standalone Single Axis Active Solar Tracker using MATLAB/Simulink

The design, modelling, and testing of a freestanding single-axis active solar tracker using MATLAB/Simulink are covered in this work. The solar tracker is suited for a variety of applications because it is wall-mountable and compact. On the photovoltaic (PV) panel, it makes use of two light-dependent resistor (LDR) sensors to measure solar irradiance. To account for varying weather conditions and user preferences, the system runs in several modes. A computer model of the solar tracker system is made using MATLAB/Simulink, enabling efficiency analysis and performance evaluation prior to implementation. The simulation results and experimental tests are consistent.

Sustainable power generation requires the use of renewable energy, especially solar energy. For converting solar energy into electricity, photovoltaic systems have grown in popularity. Active solar trackers, like the one described in this research, increase energy production by steadily pointing PV panels in the direction of the sun. Despite being simpler and less expensive, passive trackers are less effective. The various forms of solar trackers, including auxiliary bifacial solar cell-based, time-based, microprocessor-based, and their combinations, are examined in this study. Given Singapore's climate and high-rise structures, the authors suggest an active single-axis tracker as a less complicated and more useful alternative.

There are several operating modes for the proposed solar tracker system, including automatic, preset, and manual modes. It uses light-dependent resistor sensors to determine where the sun is, and an electronic system spins the PV panel using a low-speed DC motor in response. The solar tracker system, which consists of a PV panel, servo motor, battery, charger, sensors, and a microcontroller, is modelled and simulated using MATLAB and Simulink. The experimental testing validates the simulation results, which demonstrate good agreement between the fixed panel and the solar tracker system. The suggested design offers flexibility, energy efficiency, and the possibility for power generation cost savings.

The design, modelling, and testing of a freestanding single-axis active solar tracker are all presented in detail in this work. Efficiency analysis and performance evaluation are both made possible by the small and versatile system in conjunction with MATLAB/Simulink simulations. The testing findings support the solar tracker's ability to maximise energy production. The proposed technology may be advantageous for solar power applications, especially in areas with erratic weather patterns and tall structures.

2.2.5 Design of a Solar Tracking System Using the Brightest Region in the Sky Image Sensor

The study presents a novel strategy to boost solar energy conversion effectiveness. The paper suggests a technique for tracking the sun that makes use of an image sensor. The brightest area in the photograph of the sky is thought by the authors to be the location of the sun. Using an inbuilt Raspberry Pi processor to determine the location of this region's centre, servo motors are regulated to precisely follow the sun's motion. The suggested method is compared to alternative image-based sun tracking techniques, demonstrating its accuracy even under difficult circumstances like sunny days and inside structures.

Figure 2.2 : Image-based sun tracking methods

The two types of solar tracking systems are passive and active, with the latter subdivided into open loop and closed loop control systems. Cloudy days may have an impact on closed-loop systems, which frequently use photo sensors as feedback signals and are sensitive to environmental conditions. The work investigates the application of low-cost cameras and image processing methods for active solar tracking in order to address these limitations. The suggested approach finds the brightest area in the image of the sky to locate the sun, obviating the requirement for sophisticated image processing or thresholding. When compared to the Hough transform approach, the proposed method performs better and is more accurate.

A camera, servo motors, a small solar panel, and a Raspberry Pi embedded processor are used in the solar tracking system's actual implementation. The system uses the OpenCV library for image processing and the Python programming language. Under varied weather situations, it successfully captures the sun's actual centre, and the servo motors align the solar panel perpendicular to the sun's centre. Easy integration, real-time operation, and increased solar energy conversion efficiency are all features of the suggested system. In conclusion, the study addresses the shortcomings of previous methods and proposes a precise and affordable solution for solar tracking utilising image sensors.

2.2.6 Development of an Educational Solar Tracking Parabolic Dish Using Raspberry Pi

The creation and testing of an educational solar tracking parabolic dish using Raspberry Pi was the main topic of the research presented at the 2019 6th IEEE International Conference on Engineering Technologies and Applied Sciences (ICETAS). The system was created for applications requiring moderate temperatures and was intended to improve students' comprehension of principles related to heat transfer and renewable energy. The prototype included a small, portable parabolic dish solar collector with a closed-loop tracking system, a Raspberry Pi 3 controller, and an aluminium reflecting surface. Students who utilised the system for demonstration purposes gave it positive comments, which suggested that their learning experience had improved.

The study emphasized the importance of renewable energy systems and their role in meeting the increasing demand for energy production. Solar energy, in particular, was highlighted as a preferred source due to its abundance and environmental benefits. Concentrated solar power (CSP) technology, such as parabolic dish concentrators, was discussed as an effective means of generating electricity by focusing sunlight onto a receiver. The research focused on the development of a parabolic solar dish tracker with dual-axis tracking using Raspberry Pi controller. The system aimed to optimize energy output by accurately tracking the sun's trajectory, thereby improving the efficiency of solar thermal power generation.

The hardware components of the developed system were described, including the LDR module for tracking, Raspberry Pi controller for programable tracking control, H-Bridge module for motor speed control, and 12V DC motors for azimuth and tilt angle control. The solar geometry and tracking mechanism were also explained, highlighting the need for an optimal tracking scheme to maximize energy extraction from CSP technologies. The research emphasized the viability and potential of solar thermal power technology, particularly in regions like Europe, the US, India, and China. The study concluded that the designed parabolic dish tracker, with its compact and portable nature, could serve as an effective educational tool for demonstrating renewable energy concepts and enhancing students' understanding of solar thermal power generation.

2.2.7 Solar Tracker design on solar panel for STM32 microcontroller based on battery charging system

This study describes the creation of a solar tracker system for solar panels utilising a battery-charging system based on an STM32 microprocessor. Converting solar energy to electrical energy is made simple by solar panels. However, when they are placed horizontally on the ground, their effectiveness is constrained. A robotic solar tracking system is required to increase solar panel efficiency. In this study, a light-dependent resistor (LDR) sensor based on the STM32 microcontroller is used to construct a solar tracker.

The results show that installing the solar tracker increased the amount of power the solar panels produced by 27.97%. Additionally, using the solar tracker reduced the time needed to charge a 12V, 7AH lead-acid battery from 5 hours and 10 minutes to 3 hours and 30 minutes. In comparison to using static solar panels, this means that battery charging takes an hour and forty minutes less time.

Additionally, the research provides insights into solar energy principles, solar cell operation, factors influencing solar panel performance, the concept of solar trackers, the use of LDR sensors, the STM32 microcontroller, linear actuators, solar charge controllers, and batteries. The study encompassed the design of the solar tracking and battery charging system, development of the STM32 microcontroller program, fabrication of mechanical and electrical systems, and performance evaluation of the solar tracker system.

Figure 2.3 : Solar tracker framework

2.2.8 Design of Intelligent Solar Tracking Control System

The study presented in the paper titled "Design of Intelligent Solar Tracking Control System" looked at how to increase the tracking precision of stepping motors used in solar tracking systems. The system uses a fuzzy PID control technique and a microcontroller along with a number of other parts, including an angle feedback MPU6050 serial module and a four quadrant detector for sun position detection. To closely track the sun's position, the tracking system combines optical and photoelectric tracking. The tracking accuracy and stability of the fuzzy PID control system are superior than those of the deviation control and conventional PID control systems, according to experimental data. According to reports, the pitching direction inaccuracy is about 0.1 degrees, while the horizontal direction error is between 0.1 and 0.2 degrees.

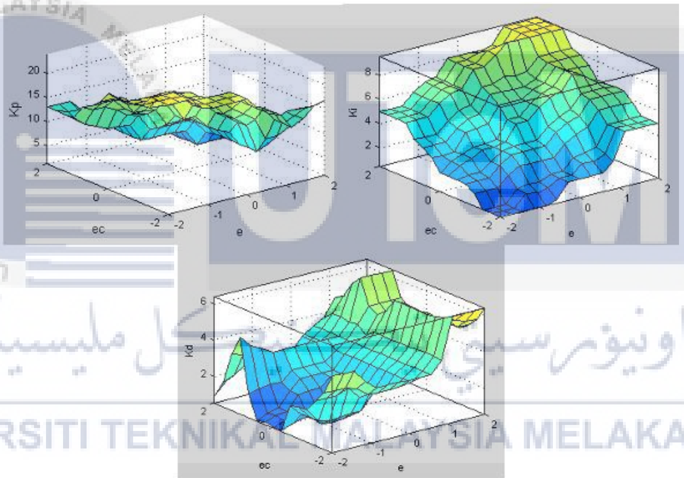

Figure 2.4 : PID output surface view

The study emphasizes the significance of accurate tracking in photovoltaic power generation technology. The authors highlight the limitations of conventional control methods, such as the nonlinear nature of the stepper motor system and the requirement for precise mathematical models. To address these challenges, the paper introduces the fuzzy PID control theory as an alternative approach. By incorporating fuzzy control rules and using the deviation and variation rate of the tracking error as input variables, the system dynamically adjusts the PID control parameters to improve tracking performance. The authors provide a comprehensive overview of the system's overall structure, including the stepping motor drive module, the four quadrant detector, and the feedback module based on the MPU6050 serial module.

The proposed system's usefulness has been confirmed by experimental examination. When PID control, deviation control, and fuzzy PID control strategies are compared, it becomes clear that the fuzzy PID method provides the best tracking accuracy and stability. The average horizontal inaccuracy is decreased to 0.1 to 0.2 degrees, while the pitching direction exhibits an error of approximately 0.1 degrees. In contrast, the classical PID control strategy exhibits larger error peaks and an average error close to 0.4 degrees. Although deviation control shows smaller errors overall, its error range remains around 0.3 degrees. These results highlight the benefits of the fuzzy PID control system, which can effectively handle ambiguous information in the system and does not rely on accurate mathematical models, eventually enhancing the performance of the stepping motor servo system for solar tracking applications.

2.2.9 Arduino Based Solar Tracking System for Energy Improvement of PV Solar Panel

The study on an Arduino-based solar tracking system is presented in the paper with the goal of enhancing photovoltaic (PV) solar panels' energy efficiency. Solar energy presents a practical alternative in Nigeria because the public electricity source is unstable. However, fixed PV panels are less efficient since they can only produce their greatest amount of energy for a short time. The researchers developed a solar tracking system using an Arduino and Light Dependent Resistors (LDRs) to measure sunlight intensity in order to solve this problem. The device uses a servo motor that is managed by an Arduino microcontroller to change the solar panel's position. According to experimental findings, a tracking solar panel generates more energy than a stationary panel, showing the potential for increased energy production.

The paper begins by discussing the importance of solar energy in Nigeria, given its abundant sunlight resources and the unreliable nature of public electricity supply. Solar energy is considered a clean and environmentally friendly alternative to fossil fuels, with the potential to reduce pollution and create job opportunities. The authors emphasize the need to maximize the energy production of PV panels by positioning them perpendicularly to the sun. Various solar panel tracking systems have been developed to achieve this, with the heliostat being a common type. The paper focuses on an Arduino-based tracking system, where LDRs detect sunlight intensity and provide input to the microcontroller, enabling the servo motor to adjust the position of the solar panel accordingly.

The components and functionality of the solar tracking system are described in the methodology section. The servo motor is controlled by the Arduino microcontroller after the LDRs measure the amount of light. The block diagram and flow chart for the system are shown, and simulation with Proteus software validates its operation. The tracking solar panel's performance in comparison to a fixed panel in experimental observations shows increased efficiency. Power readings obtained at various times of the day reveal that the fixed panel's energy production is constrained while the tracking system efficiently captures the greatest amount of sunshine. The paper concludes by suggesting future improvements such as using more sensitive and cost-effective sensors to further enhance efficiency and reduce costs, making the system suitable for industrial-scale deployment in countries like Nigeria and sub-Saharan Africa.

2.2.10 Dual Axis Solar Tracker with IoT monitoring system using Arduino

The creation of a solar tracking system is covered in the article "Dual Axis Solar Tracker with IoT Monitoring System Using Arduino" that was printed in the International Journal of Power Electronics and Drive System (IJPEDS). The writers of the article are Universiti Tun Hussein Onn Malaysia's Green and Sustainable Energy Focus Group members Mohamad Nur Aiman Mohd Said, Siti Amely Jumaat, and Clarence Rimong Anak Jawa. Arduino Uno is the system's primary controller. The project's findings demonstrate that, in comparison to a single axial solar tracker, a two-axis solar tracking system produces more power, voltage, and current.

The significance of solar energy as a renewable and safe source of electricity is emphasised throughout the essay. It illustrates how a solar tracking device that tracks the sun's path might increase the efficiency with which solar energy is captured. With Arduino Uno serving as the primary controller, the authors created a dual-axis sun tracker. The device employs two servo motors to spin the solar panel in response to the detected sun's light source and light-dependent resistors (LDRs) for sunshine detection. They also created an IoT monitoring system, comparing its effectiveness to a single axial solar tracker, and used a

WiFi ESP8266 device to store data. The dual-axis solar tracking system produced more power, voltage, and current, according to the data.

Figure 2.5 : Ubidots platform

The procedure for creating the dual-axis solar tracker is described in the research methodology section. Development of both software and hardware is involved. The movement mechanism of the solar tracker is tested as part of the software development process utilising simulation testing with the Proteus programme. Utilising the software Sketch Up, the hardware development process entails designing and building the prototype. Photovoltaic panels and motor brackets are the only components of the prototype. The Ubidots platform was used by the authors during outdoor testing to assess the solar panel's performance and keep track of variables including voltage, current, and power.

2.2.11 Dual Axis Solar Tracking System in Perlis, Malaysia

The design and construction of a low-cost active dual-axis solar tracking system that senses the location of the sun using light-dependent resistors (LDR) are presented in this study. The solar photovoltaic (PV) panel must constantly face the sun perpendicularly in order for the system to generate the most energy and operate most effectively. The position of the solar panel is altered based on the LDR readings by a DC geared motor that is moved by an Arduino Uno microcontroller. When the dual-axis solar tracker's performance is compared to that of a fixed solar tracking system, the dual-axis system performs 44.7% better.

An eco-friendly and sustainable form of energy is solar power. However, as the power production is inversely proportional to the brightness of the light, the position of the sun has an impact on the efficiency of solar photovoltaic panels. Solar tracking devices are used to continuously move the PV panel's position to face the sun in order to get around this restriction. The active dual-axis design of the solar tracker used in this study enables tracking of the sun's movement in both horizontal and vertical directions. The solar panel is controlled to stay perpendicular to the sun all day long using LDR sensors and an Arduino Uno microprocessor.

The dual-axis solar tracking system's hardware design features a 3D model with movable and fixed joints. An inner and outer rectangular frame, a stand, and DC motors for rotation make up the system. The LDR sensors are carefully positioned to measure light intensity and give the microcontroller input. Through the use of DC motors, the control system moves the solar panel in accordance with sensor readings. The power output of a dual-axis tracking system and a stationary solar tracking system were compared experimentally. The dual-axis system beat the fixed system, producing a 44.7% higher power yield, according to the results.

2.3 Comparison Between Past Projects

Table 2.1 : Comparison between past projects

Project Name	Author	Controller	Method	Result
Microcontroller-Based Two-Axis Solar Tracking System	Lwin Lwin Oo, Nang Kaythi Hlaing	PIC 16F84A	Using an assembly programming language-equipped PIC 16F84A microcontroller, a two-axis solar tracking system is created. Using light dependent resistors (LDRs), the movement of the sun is monitored. Two 12V, 6W DC gear box motors are used to move a parabolic reflector.	The main objective is to design and implement a two-axis solar tracking system prototype using a PIC microcontroller. The system's goal is to increase solar energy collecting efficiency by carefully following the

			A laser pointer is used to make sure the reflector is focused precisely. Helix gears in combination with worm and worm wheel DC gear box motors provide the vertical and horizontal motion. Time delays are built into the system to allow for precise motor stepping.	sun's course throughout the day and utilising a parabolic reflector in the process.
Solar Tracking System using Microcontroller	Priyanjan Sharma, Nitesh Malhotri	AT89S52	Light-dependent resistors (LDRs) and a microcontroller are both components of the solar tracker system. The microcontroller receives signals from the LDRs when they sense sunshine. Using these signals as input, the microcontroller instructs the stepper motor to move the solar panel into the best position for energy production. To keep the solar panels aligned perpendicular to the sun's rays and track the sun's movement, the system uses a single-axis tracker.	The implementation of the solar tracking system led to a significant increase in power output, ranging from 30% to 60% compared to a fixed system. Through a comparative analysis of power generation between the rotating solar panel and the fixed mount at different times of the day, the rotating panel consistently exhibited higher power production. Moreover, the single-axis solar tracker demonstrated a power efficiency that

				was 13% higher than the fixed mount.
Design of a Solar Tracking System Using the Brightest Region in the Sky Image Sensor	Ching-Chuan Wei, Yu-Chang Song, Chia-Chi Chang, Chuan-Bi Lin	Raspberry Pi	In order to complete the project, the brightest area of the sky image must be located by looking for locations with the highest grey level values. It is presumable that these spots line up with where the sun is. By calculating the arithmetic averages of the coordinates of the recognised brightest region, the approximated sun centre is ascertained.	The method put out shows exceptional accuracy in locating the sun's centre. The installed solar tracking system expertly positions the photovoltaic panel to face the sun directly, resulting in increased conversion efficiency from solar energy.
Solar tracker design on solar panel for stm32 microcontroller based on battery charging system	H.H. Rangkuti, N.P. Sinaga, and F. Ariani	TM32 ARM Cortex-M microcontroller	An STM32 microcontroller and a light-dependent resistor (LDR) sensor are used in the solar tracker system. The system had a number of components, including photovoltaic modules, motors, batteries, sensors, and controllers. The study included the creation of both mechanical and electrical systems, the recovery of data, and the design of the solar tracking mechanism and battery charging	The power produced by the solar panels increased by 27.97% as a result of using the solar tracker system. With the use of the solar tracker, the time needed to charge a 12V, 7AH lead-acid battery went from 5 hours, 10 minutes when utilising stationary solar panels, to 3 hours, 30 minutes. In comparison to stationary solar panels, this resulted in a

			system. It also included the creation of an Arduino IDE programme for the microcontroller.	reduction of 1 hour and 40 minutes in the time required to charge the battery.
Dual Axis Solar Tracker with IoT Monitoring System Using Arduino	Mohamad Nur Aiman Mohd Said, Siti Amely Jumaat, Clarence Rimong Anak Jawa	Arduino Uno	The project developed a dual-axis solar tracker system using Arduino Uno as the main controller. Four light-dependent resistors (LDRs) were added into the system to detect sunlight and regulate light intensity. Two servo motors were used to line the solar panel with the position of the sun. A WIFI ESP8266 device served as an intermediary, facilitating connection between the system and an IoT monitoring system and storing the data gathered. The effectiveness of a dual-axis solar tracker system and a single-axis solar tracker were compared.	In terms of power, voltage, and current generation, the dual-axis solar tracking system outperformed the single-axis sun tracker. A review of the system's effectiveness revealed improvements in the generation of electricity. The project's goal was to increase the efficiency of solar panels by carefully tracking and aligning with the sun's path, resulting in better sunlight detection and increased power production.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The methodology encompasses the procedures employed to accomplish the project's objectives, systematically and theoretically, by utilizing principles from a specific field of knowledge. This project involves two main components: hardware installation and microcontroller programming using ESP32.

The primary aim of this project is to utilize ESP32 in the development of an IoT-based smart solar tracking system, with the goal of optimizing power generation. To achieve these objectives, various components such as the microcontroller, sensors, actuators, and modules, along with the Arduino IDE and TinkerCad, are employed to facilitate the development process. This chapter includes a block diagram for hardware development and a program flowchart for software development.

3.2 Hardware Development

The hardware development for an IoT based smart solar tracking system for optimal power generation using NodeMCU and Blynk application involves assembling the necessary components and connecting them to create a functional system..

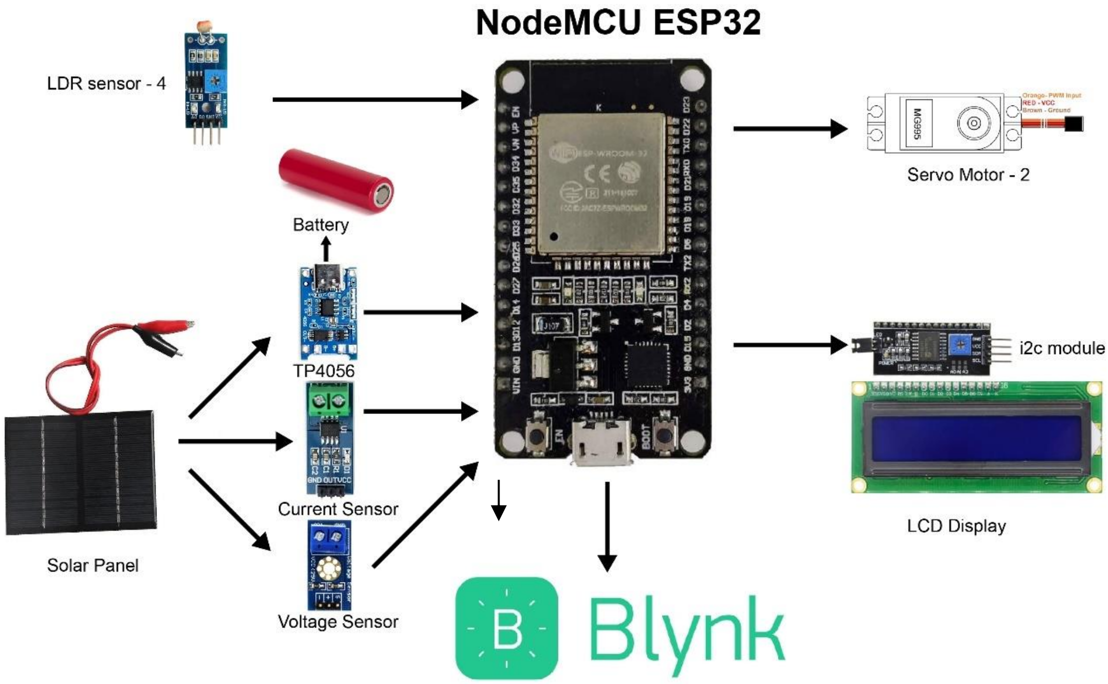

Figure 3.1 : Block Diagram

Brief explanation of each component:

ESP32 : The ESP32 is a versatile Wi-Fi module designed for wireless communication. When integrated, it facilitates a seamless connection with the Blynk application. This enables users to remotely monitor and control the smart solar tracking system using their smartphones or other connected devices.

LDR sensors : The intelligent solar tracking system uses Light Dependent Resistors (LDRs) as input sensors. These sensors detect how much light is shining on the solar panels. The microcontroller is informed about the intensity of the sunshine by feedback from a number of LDR sensors, which is then utilised to decide where the solar panels should be placed.

TP4056 and Solar Panel : The TP4056 is a solar panel charging module used to charge and control the power supply to the system. It ensures the batteries connected to the solar panels are charged properly. The solar panels themselves are the primary power source of the system, converting sunlight into electrical energy.

Servo motors : In the hardware design, servo motors are employed as output components. Based on the information the ESP32 provides, these motors are in charge of changing the position of the solar panels. The solar panels may be slanted or changed to follow the path of the sun throughout the day by rotating the servo motors, maximising their solar exposure and maximising electricity production.

Voltage sensor : A voltage sensor for a solar panel is a device that measures the electrical output produced by the solar panel. It helps users keep track of how much electricity the solar panel is generating in real-time. This information is useful for understanding how well the solar panel is working and making sure it's producing energy efficiently.

Current sensor : The sensor keeps tabs on how much electrical power the solar panels are making. This helps to know if they're working properly and making enough energy.

LCD display : LCD display in this solar panel system to shows how much battery is left and the power from the solar panel. It helps users see if their system is working well.

The intelligent sun tracking system is controlled by ESP32 board. It gathers data from the LDR sensors and analyses it to determine where the solar panels should be placed. Additionally, the servo motors are managed by ESP32 so that the solar panels can be positioned appropriately.

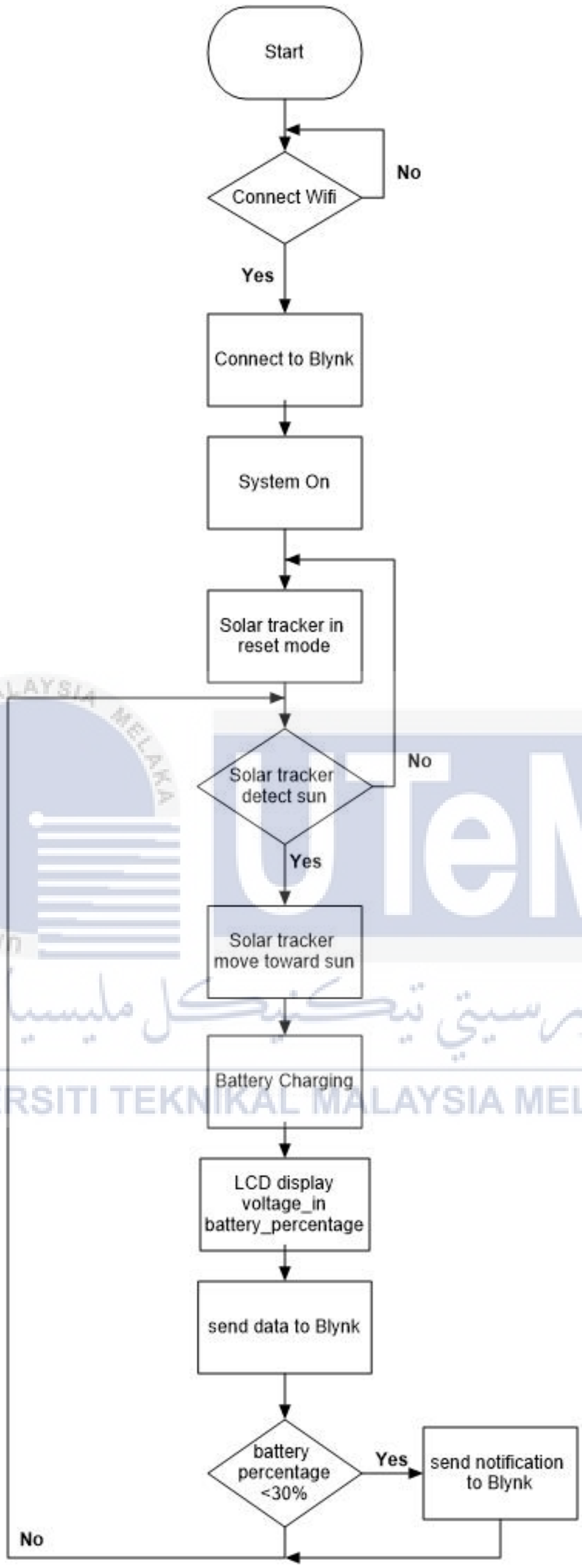

Figure 3.2 : Program Flowchart

The system begins with initializing the hardware components. The system then reads data from the LDR sensors to determine whether it is night time or not. If it is night time, the

solar panel is set to the idle position to conserve energy. If it is not night time, the solar panel is set to the starting position.
Afterwards, the system determines the position of the sun based on the data obtained from the LDR sensors. The servo motors are then moved horizontally and vertically to the calculated positions, aligning the solar panel with the sun's position for optimal power generation. The system sends relevant data, such as battery percentage and light intensity, to the Blynk application for monitoring purposes. This process is repeated continuously until the stop button is pressed, indicating the end of the flowchart.

3.2.1 ESP32

Figure 3.3 : ESP32

The ESP32 is a multipurpose microcontroller module with Bluetooth, Wi-Fi, and a dual-core Xtensa LX6 CPU that is intended for embedded systems. The ESP32 is unique in technology because of its ability to combine high processing power with wireless capabilities. This combination makes it useful for a wide range of applications, including robotics and Internet of Things (IoT) devices.

The dual-core architecture of the ESP32 is a crucial component of its technique. The microcontroller's total performance is improved via parallel processing, which is made possible by the two cores. This is especially helpful for applications that require real-time responsiveness and multitasking. The cores' cooperative and independent modes of operation allow for flexibility in managing several tasks at once.

Wi-Fi and Bluetooth connectivity bundled into one unit is another important feature. Due to its technique, the ESP32 is a great option for projects that need wireless data interchange because it allows for smooth contact with other devices or networks. Developers may construct smart and connected solutions with the ESP32's methodology, whether it's sending sensor data to a remote server or creating a communication link between devices.

The ESP32's approach to accessibility is enhanced by its support for numerous programming languages and development frameworks. A wide range of skill sets and preferences are accommodated by the options available to developers: the Arduino IDE, MicroPython, or the ESP-IDF (Espressif IoT Development Framework). Because of its versatility, the ESP32 is a desirable choice for both novice and seasoned developers, promoting a strong and welcoming development community.

The ESP32's technique is further distinguished by a wide range of peripherals and features, including as GPIO ports, pulse-width modulation, and analog-to-digital converters. Because of its adaptability, a multitude of sensors, actuators, and other devices can be interfaced with, increasing the potential for imaginative and inventive applications. The ESP32's methodology is centred on offering an accessible, adaptable, and strong foundation for creating networked embedded systems.

3.2.2 Solar Panel

Figure 3.4 : Solar Panel

Photovoltaic (PV) or solar panels are technologies that use light from the sun to generate electricity. They are built to collect solar energy and transform it into useful electrical energy. A semiconductor material, usually silicon, which can produce an electric current when exposed to sunlight, makes up the majority of a solar panel. The solar panels are made up of many connected solar cells that each have a layer of positively charged holes and a layer of negatively charged electrons. An electric current is produced when sunlight strikes solar cells because the photons from the sunshine excite the electrons.

Its specs may change depending on the solar panel technology used. Monocrystalline solar panels, which are created from a single crystal structure, are the most popular kind. Though their manufacturing costs are higher, these panels often offer higher efficiency. Contrarily, polycrystalline solar panels, which are often less expensive but slightly less efficient due to their use of numerous crystal structures, are created. Thin-film solar panels are one of the other new technologies; they are lightweight and flexible, making them suited for particular applications.

3.2.3 Battery charging module (TP4056)

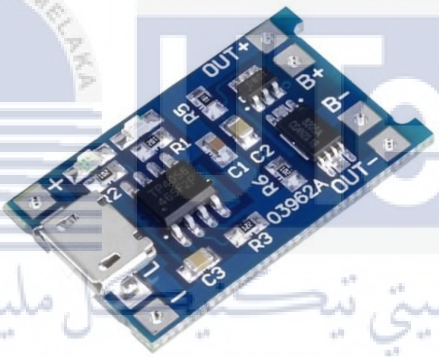

Figure 3.5 : TP4056

A well-liked integrated circuit (IC) for charging lithium-ion batteries is the TP4056. It is made to offer single-cell lithium-ion or lithium-polymer batteries a quick and effective charging option. Constant-current/constant-voltage (CC/CV) charging is the approach used by the TP4056.

In the first stage of the charging process, the TP4056 applies a constant current to the battery, typically set by an external resistor connected to the IC. This current level is determined based on the battery's capacity and the desired charging rate. The TP4056 regulates the current flow to prevent overcharging and damage to the battery.

Once the battery voltage reaches a predefined threshold, typically around 4.2 volts per cell, the TP4056 enters the second stage of charging. In this stage, the IC switches to a constant voltage mode, where it maintains a steady voltage across the battery terminals. The charging current gradually reduces as the battery approaches full capacity.

Safety features like reverse polarity protection, short-circuit protection, and over-temperature protection are included in the TP4056. These characteristics assist in protecting the battery and avoiding potential risks when it is being charged.

3.2.4 LDR Sensor (Photoresistor)

Figure 3.6 : LDR Sensor

A passive electrical component called an LDR sensor, often referred to as a Light Dependent Resistor or a photoresistor, changes in resistance in response to the amount of light that strikes its surface. It is frequently utilised in many applications that involve the control and sensing of light. It is an electronic gadget that changes resistance in response to the amount of light hitting its surface. They are frequently utilised in numerous applications that call for the measuring and detection of light. An LDR sensor's basic operation is based on the conductivity of elements that are frequently found in LDRs, such as cadmium sulphide (CdS) or lead sulphide (PbS).

When light strikes the surface of an LDR, the photons of light excite the electrons in the material, causing them to move and generate an electric current. This current flow leads to a decrease in resistance across the LDR. Conversely, when the ambient light decreases or is blocked, fewer photons reach the LDR's surface, resulting in reduced electron movement and a corresponding increase in resistance.

The change in resistance of an LDR allows it to be used as a sensor for light intensity. By measuring the resistance of the LDR using an appropriate circuit, the intensity of light can be determined. The resistance of an LDR is typically high in the dark and low in bright light conditions.

When selecting the LDR sensor, several specifications should be considered. The resistance range is an essential parameter as it determines the sensitivity of the sensor to light. The spectral response indicates the range of wavelengths to which the LDR sensor is sensitive. It is important to choose an LDR sensor with a spectral response that matches the intended application such as to detect the solar intensity. Additionally, the response time of the sensor refers to the speed at which it reacts to changes in light intensity.

3.2.5 Servo Motor

Figure 3.7 : Servo Motor

Similar to the SG90 servo motor, the MG995 servo motor is a frequently used part in the field of robotics and electronics. This lightweight and small motor's purpose is to give precise control over angular movements. Both mechanical parts and electrical impulses are used in its operation.

The MG995 servo motor is composed of three primary components: a DC motor, a control circuit, and a feedback system. The control circuit decodes electrical impulses from an external source (such a microcontroller or computer) and transforms them into control signals for the motor, while the DC motor produces the rotational force. The control circuit receives information about the motor's present position from a feedback system, which is frequently a potentiometer. This information allows for precise adjustments to its rotation.

The pulse width modulation (PWM) signals are used to control the MG995 servo motor. The pulse width of the PWM signal—typically at a fixed frequency of about 50 Hz—determines the intended motor position. The control circuit modifies the motor based on its analysis of the pulse width. A motor may move to a different angle for a pulse width of 1.5 milliseconds, for instance, whereas shorter or longer pulses lead the motor to move towards the centre.

It's crucial to remember that, similar to the SG90, the MG995 servo motor has a restricted range of motion, typically 180 degrees, though this might change depending on the model. Furthermore, in comparison to bigger servo motors, the motor's torque is comparatively modest, making it appropriate for small-scale applications that prioritize precise positioning over high power.

3.2.6 Voltage Sensor

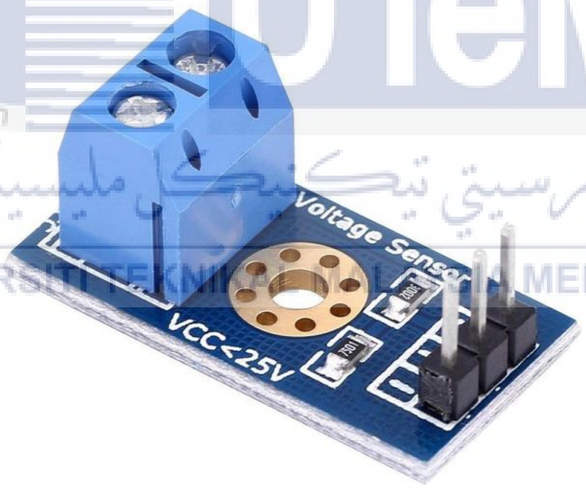

Figure 3.8 : Voltage Sensor

A voltage sensor is a specialised instrument used in photovoltaic systems to detect the voltage, or electrical potential, generated by the solar panels. This sensor is essential for evaluating the solar power generation system's functionality and overall health. In essence, it tells us how well the solar panels are turning sunlight into power by measuring the strength of the electrical output they produce.

The voltage sensor, which is integrated into the solar panel arrangement, continuously measures and reports the voltage levels. Users and system operators can use this data to assess the efficiency of the solar panels and spot any problems that can compromise energy output, which makes it vital information. A decrease in voltage, for example, could be a sign of shadowing on the panels, a broken panel, or other operational inefficiencies.

Practically, the voltage sensor helps solar energy systems be optimised by giving instantaneous data on the electrical performance of the solar panels. With the help of this information, users may make well-informed decisions, take quick action in the event of a problem, and guarantee the solar power system runs as efficiently as possible.

3.2.7 Current Sensor

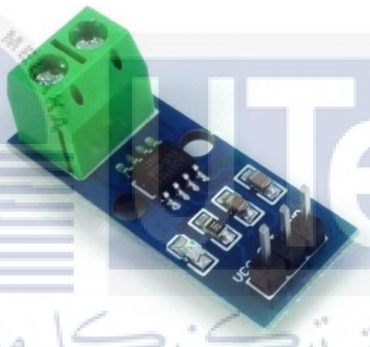

Figure 3.9 : Current Sensor

In the context of a solar panel system, a current sensor is an apparatus intended to gauge the electric current passing through the system. It is essential for tracking the real flow of power produced by the solar panels. The current sensor records the amount of electricity generated at any one time.

The current sensor, which is installed inside the solar panel system's electrical circuit, gives current information on the amount of electric current being generated in real time. This information is useful for evaluating the system's functionality and spotting any anomalies. For example, an abrupt decrease in current could indicate problems with the panels' shading, a broken panel, or other operational difficulties.

Put otherwise, the current sensor provides consumers with information on how well their solar panels are actively generating electricity. It allows users to take corrective action and guarantee the best possible operation of the solar power generation system by monitoring the current flow, which facilitates the quick discovery of any problems.

3.3 Software Development

3.3.1 Arduino IDE

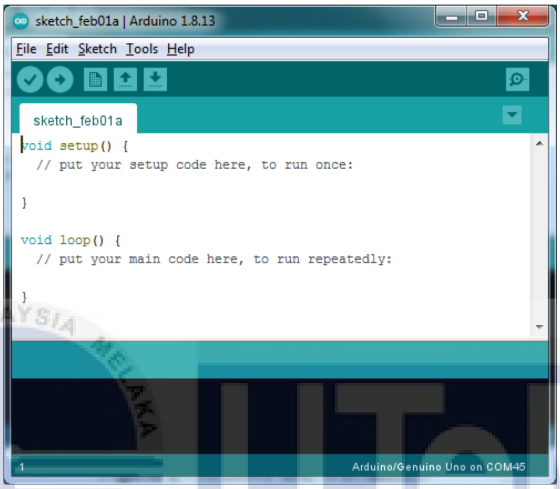

Figure 3.10 : Arduino IDE interface

Arduino is an open-source gadget based on simple hardware and software that may be used to create electrical appliance projects. The Arduino IDE Software compiles the programming code, converts it to binary, and transfers it to the circuit board through serial port connection, as illustrated in Figure 13. Furthermore, the Arduino employed the C++ programming language, which is relatively easy and makes learning to code simpler since it uses conventional serial protocol communication, which connects to a computer through USB.

Because it simplifies the process of working with microcontrollers, the Arduino software is simple to use for novices. Furthermore, the benefits of Arduino are that it is a low-cost programmable board compared to other microcontroller platforms, which is why most 9 people utilise it. It is a popular first pick since it is simple and convenient. In addition, the Arduino software enables users to attach shields, which are pre-built circuit boards that give extra features that allow users to experiment with more sensors, displays, and inputs. There are a variety of Arduino boards that may be used for various purposes. The Arduino UNO is a popular Arduino family board and a good option for a beginning.

To program an Arduino board using the IDE, users follow a simple workflow. They write their code in the IDE's editor, which provides syntax highlighting and basic code suggestions. Once the code is written, users verify it to check for any errors and compile it into machine language specific to the Arduino board. If the compilation is successful, users can then upload the compiled code to the board via a USB connection.

3.3.2 Blynk Software

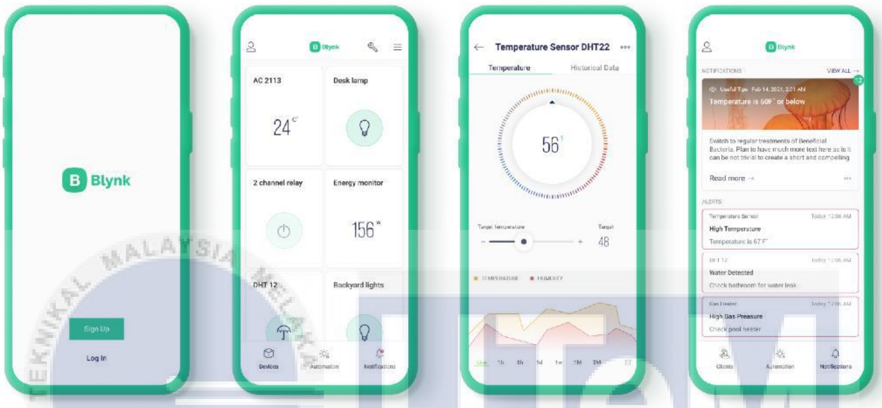

Figure 3.11 : Blynk interface

Blynk is a software development methodology that focuses on the rapid prototyping and development of Internet of Things (IoT) applications. It provides a platform for creating mobile apps that interact with various hardware devices, enabling users to control and monitor IoT projects seamlessly. The Blynk methodology emphasizes simplicity and ease of use, allowing developers to quickly build IoT applications without extensive coding knowledge.

The core concept of Blynk revolves around the idea of virtualizing hardware components and creating a visual interface for controlling them. Developers can choose from a wide range of supported hardware platforms, such as Arduino, Raspberry Pi, ESP8266, ESP32 and more. They can then use the Blynk mobile app builder to create a customized user interface, including buttons, sliders, gauges, and other interactive elements.

One of the key advantages of the Blynk methodology is its cloud-based infrastructure. Blynk provides a cloud server that acts as a bridge between the hardware devices and the mobile app. This eliminates the need for complex networking configurations and allows for easy remote access to IoT projects. The cloud server also offers features like data logging, notifications, and project sharing, enhancing the overall functionality of Blynk-based applications.

Blynk follows a widget-based approach, where developers can choose from a vast library of pre-built widgets to add functionality to their mobile app. These widgets are designed to interact with the hardware components, enabling actions like turning on/off lights, adjusting motor speed, reading sensor data, and more. Additionally, Blynk supports various communication protocols, including Wi-Fi, Ethernet, Bluetooth, and cellular connectivity, ensuring compatibility with a wide range of devices.

The Blynk software methodology offers a user-friendly and efficient approach to IoT development. It simplifies the process of creating IoT applications by providing a comprehensive platform, cloud infrastructure, and an extensive library of widgets. With Blynk, developers can rapidly prototype and deploy IoT projects, bringing their ideas to life quickly.

3.3.3 TinkerCad

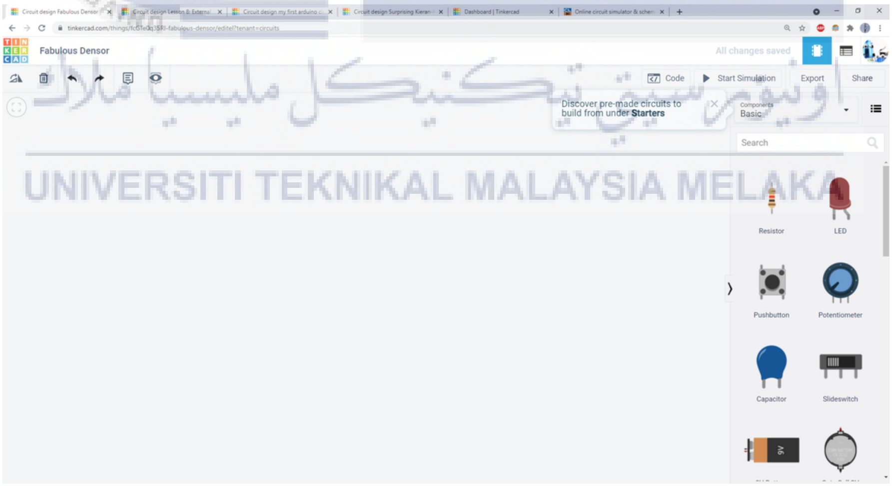

Figure 3.12 : TinkerCad interface

In the developing of IoT-based smart solar tracking system using Arduino and Blynk, Tinkercad can be utilized as a virtual simulation platform to design and test the circuitry before implementing it physically. Tinkercad provides a user-friendly interface and a wide range of electronic components, enabling users to create and connect the circuit elements required for the solar tracking system.

In Tinkercad, the circuit can be designed by selecting and placing the necessary components, such as LDR sensors, servo motors, and ESP32 module, onto the virtual work area. These components can be interconnected by simply dragging and dropping wires between them, simulating the electrical connections required for the system.

Once the circuit design is complete, Tinkercad allows for simulation and testing. The virtual environment enables users to verify the functionality of the circuit, ensuring that the solar tracking system operates as intended. By providing a simulated real-world experience, Tinkercad helps in identifying any design flaws or issues before physically implementing the system.

3.4 Data Collection

Information is gathered from the Internet of Things-based smart solar monitoring system as part of the data collection phase of this project. Solar panel placement is continuously optimised for maximum power generation by gathering real-time data from light sensors.

When analysing the solar tracking system's effectiveness, statistical analysis is essential. In the experiment, for example, the system's response to changing light conditions is monitored, and patterns are identified in the data gathered using statistical analysis. Presenting the data in an understandable way is the aim, usually achieved by using visual aids like graphs or charts. These graphs, which include bar charts, scatter plots, and pie charts, are used to show patterns and trends in the smart solar tracking system's performance.

In summary, this project's statistical analysis entails handling light sensor data in order to assess the effectiveness and responsiveness of the Internet of Things-based solar tracking system. In order to optimise solar panel alignment for better energy generation, the data is presented via charts and graphs, which improve comprehension of the system's behaviour.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This section describes the results, analysis and discussion for all of the data collected from the system to determine the performance of the system and modified it to achieve the best results for this IoT based smart solar tracking system for optimal power generation using NodeMCU and Blynk application . In this chapter, it shows the result of hardware prototype, and the experimental of the smart solar tracking system.

4.2 Results and Analysis

Using an IoT-based strategy via Blynk for data collecting, data was collected with the assistance of LCD display in order to evaluate and analyse the critical solar tracking system parameters. Real-time tracking and recording of critical performance indicators for the solar panels was made possible by the incorporation of IoT technology.

Blynk and IoT-enabled sensors were used in the data collection process to monitor voltage levels at different stages of solar exposure. First, voltage was measured when the sun was directly overhead the solar panel; second, voltage was measured when the solar panel was actively tracking the sun. Dynamic variations in solar incidence were captured by this iterative procedure, which was carried out on a regular basis throughout the day.

Figure 4.1 : Calibration of LDR sensors

Figure 4.2 : Blynk Interface

To fine-tune the solar tracking system, the sensitivity of all LDR sensors is calibrated to precisely detect sunlight. This calibration procedure involves adjusting the sensors as shown in figure 4.1 to be more responsive to changing light conditions, assuring accurate tracking of the sun's movement for maximum solar energy absorption. The collected data from these calibrated sensors is easily examined via the Blynk interface in the figure 4.2, providing real-time insights into the system's performance and capacity to align with sunlight for increased energy generation efficiency.

4.2.1 Static Solar and Smart Solar Data Acquisition

In the experimental phase of the project, data collection was critical in determining the performance of both static solar panels and those integrated with the smart solar tracking system. Every hour, voltage and current were methodically measured from the static solar panel, and the process was performed twice to assure precision and consistency. This method sought to obtain a full understanding of the static panel's energy production properties throughout various time intervals. The gathered statistics were not only calculated, but also averaged over two repetitions, providing a solid foundation for analysing the static solar panel's baseline efficiency.

In contrast, the solar panel with the smart solar tracking system underwent a more thorough data collection process. Voltage and current readings were scrupulously recorded every hour, and the process was repeated four times to obtain a comprehensive dataset. The increased number of repetitions was intended to provide a more representative picture of the solar tracking system's energy generation performance under varied situations. The obtained data, like the static panel, were subjected to calculations and averaged over four repetitions. This careful approach enables a full comparison analysis of static and tracked solar panels, allowing for a thorough assessment of the smart solar tracking system's impact on energy production efficiency.

Notably, there is an absence of data collected from both system at 2 pm for all of the test sessions. Skipping this time helps to avoid issues like battery overheating and other issues that could disrupt data collecting, maintaining the system's safety and optimal performance.

4.2.1.1 Static Solar System

The data as in figure 4.1 are from the static solar panel and was obtained twice, on different days, with the same equipment as the smart system. However, for the static panel, the motor and tracker was unplugged. This allows to evaluate how much energy the static panel generates versus the smart system, emphasizing the importance of the solar tracker.

Table 4.1 : Data from Static Solar System

Time	Average Voltage Measured (V)	Average Current Measured (A)	Power (W)
10am	1.38	0.11	0.1518
11am	2.14	0.12	0.2568
12pm	2.49	0.14	0.3486
1pm	3.68	0.16	0.5888
3pm	3.44	0.16	0.5504
4pm	3.25	0.13	0.4225
5pm	2.91	0.13	0.3783

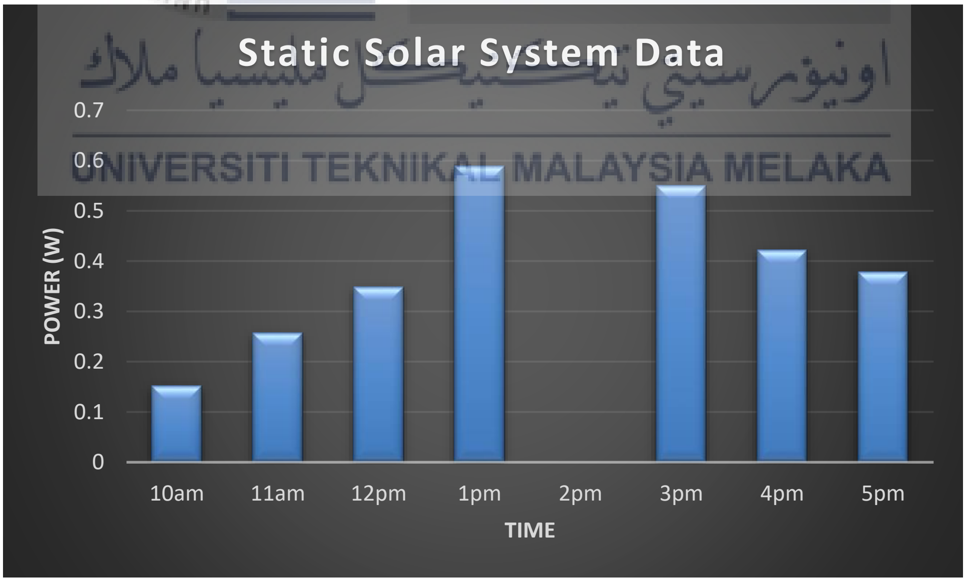

Figure 4.3 : Static Solar System Data

4.2.1.2 Solar with Tracking System

The data acquired in figure 4.2 by the smart solar tracking device is from four separate days. Measuring four times provides a clearer view of the system's performance in varied scenarios, making the assessment more reliable.

Table 4.2 : Data from Solar with Tracking System

Time	Average Voltage Measured (V)	Average Current Measured (A)	Power (W)
10am	3.63	0.17	0.6171
11am	3.74	0.19	0.7106
12pm	4.44	0.18	0.7992
1pm	4.73	0.22	1.0406
3pm	3.88	0.17	0.6596
4pm	3.45	0.17	0.5865
5pm	4.14	0.17	0.7038

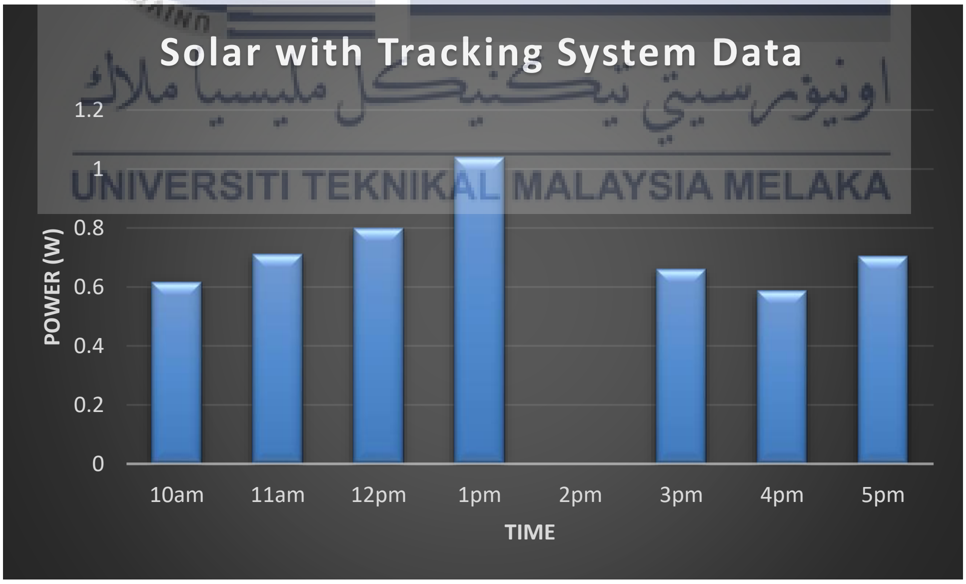

Figure 4.4 : Solar with Tracking System Data

4.2.2 Data Comparision

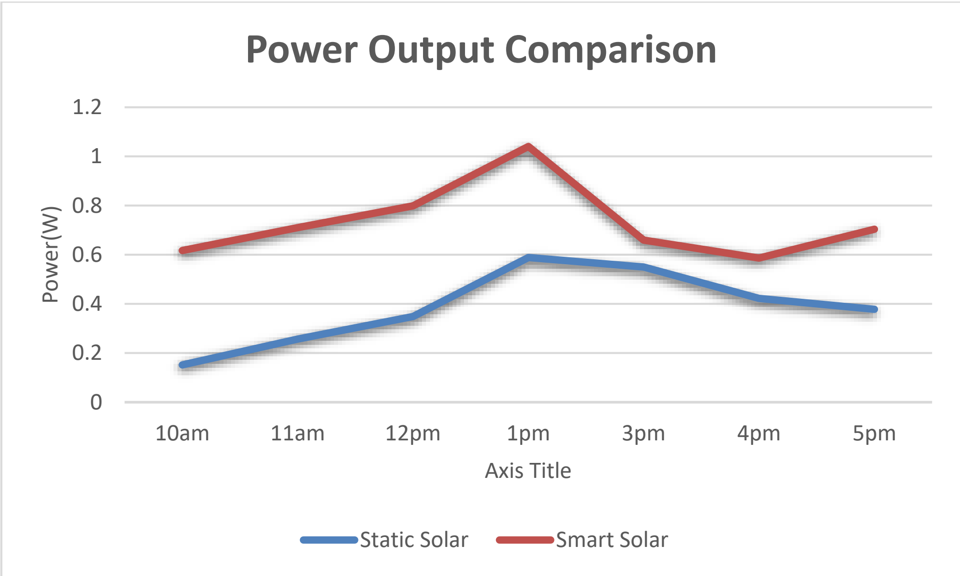

Figure 4.5 : Power output comparison

As shown in figure 4.5, solar panel tracking system outperforms static solar panels in terms of power gain because it can dynamically track the sun's movement throughout the day. Unlike static panels, which remain set in one position, solar tracking systems vary their orientation to maximise sunlight absorption. This consistent alignment with the sun enables more efficient capture of solar energy, resulting in increased power generation. The dynamic adaptability to shifting sunlight angles guarantees that the solar panels receive sunlight more directly, hence increasing their output. In contrast, static panels have a limited ability to fully utilise available sunlight, resulting in decreased energy generation. Furthermore, the tracking system's reactivity improves its effectiveness in changing weather circumstances, making it a more dependable and effective alternative for capturing solar energy.

4.2.3 Solar Panel Charging Battery

The table 4.3 shows the average charging time obtained after three consecutive test runs. These averaged numbers provide a more steady and reliable depiction of the system's charging performance, reducing the impact of possible fluctuations or outliers in individual test sessions.

Table 4.3 : Average Charging Time

Weather	Average Charging Time (10-100%)
Cloudy	1h 42 min
Partly Cloudy	1h 21min
Sunny	1h 3min

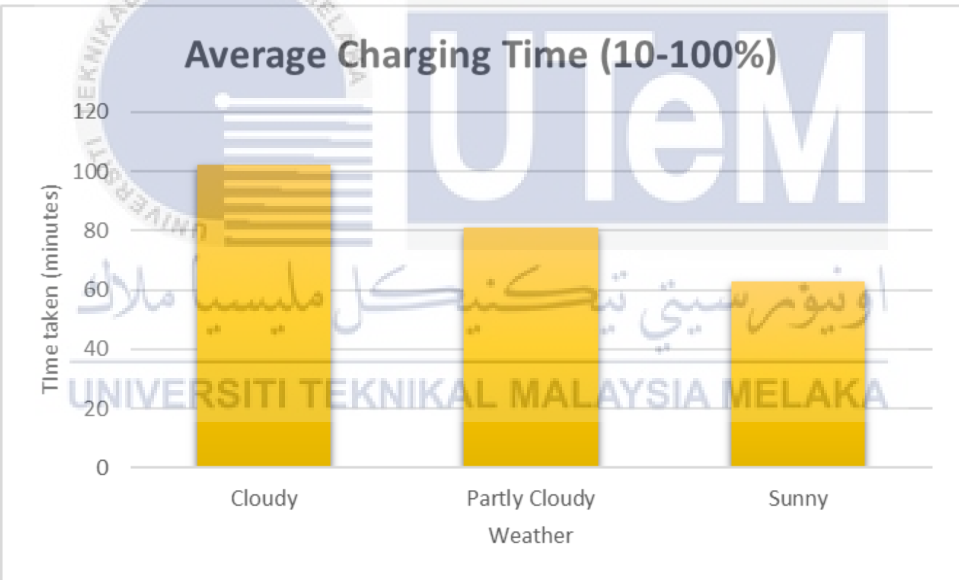

Figure 4.6 : Average Charging Time

4.2.4 Hardware Result

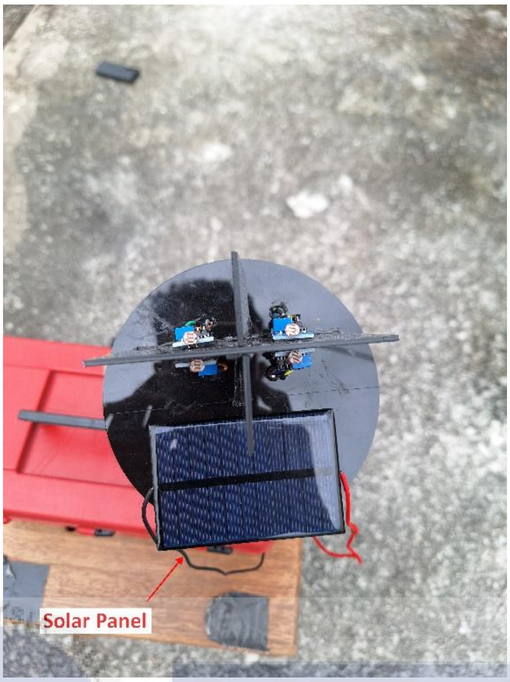

Figure 4.7 : Component System -1

Figure 4.8 : Component System -2

Figure 4.9 : Component System -3

4.2.5 Hardware Design

The hardware design, shown in the figure 4.10, includes an ESP32 microcontroller as the brain of the system. Four LDR sensors detect light, two servo motors move the solar panels, and voltage and current sensors monitor how they generate electricity. The system's output is presented locally on an LCD screen, as well as remotely via the Blynk app. In addition, a TP4056 regulates the rate at which the solar panel charges the battery. This setup ensures that the smart solar tracking system functions properly by using sensors, a microcontroller, motors, and display components to improve solar energy efficiency.

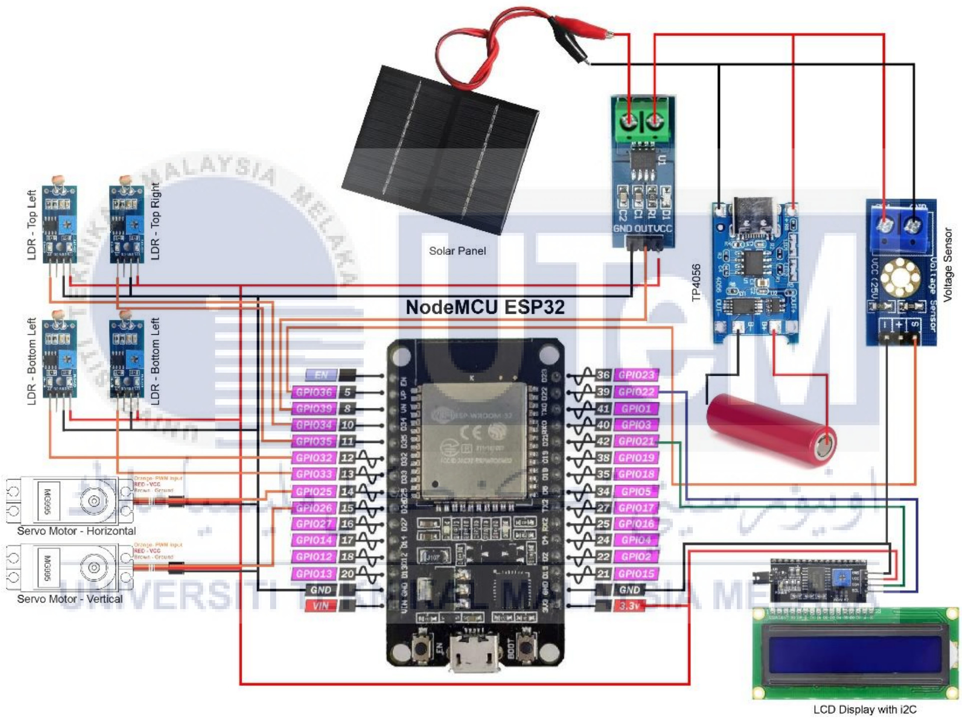

Figure 4.10 : Circuit Diagram

4.2.6 Software Setup

In the goal of constructing an advanced solar tracking system that optimises solar panel location based on the sun's movement, Blynk integration is critical to enabling seamless monitoring and management. By combining IoT technology and the Blynk app into the system, users can remotely monitor the solar tracking device. This allows users to easily modify and increasing the overall efficiency of the solar power system. The Blynk app provides an easy-to-use interface for monitoring real-time data and receiving status updates to maximise power production.

Furthermore, integrating Blynk into the solar tracking system improves the user experience by offering useful insights and data. Users can get complete information about the solar panel's performance, including real-time data on energy production and sunshine exposure. Users of the Blynk app can establish preferences, receive system status or issue notifications, and view historical data patterns. This not only provides preventive maintenance, but also allows users to make data-driven decisions for ongoing system improvement. The combination of precise solar monitoring, IoT connectivity, and user-friendly data visualisation via Blynk helps to the development of an intelligent and efficient solar power generating solution that prioritises environmental sustainability and user convenience.

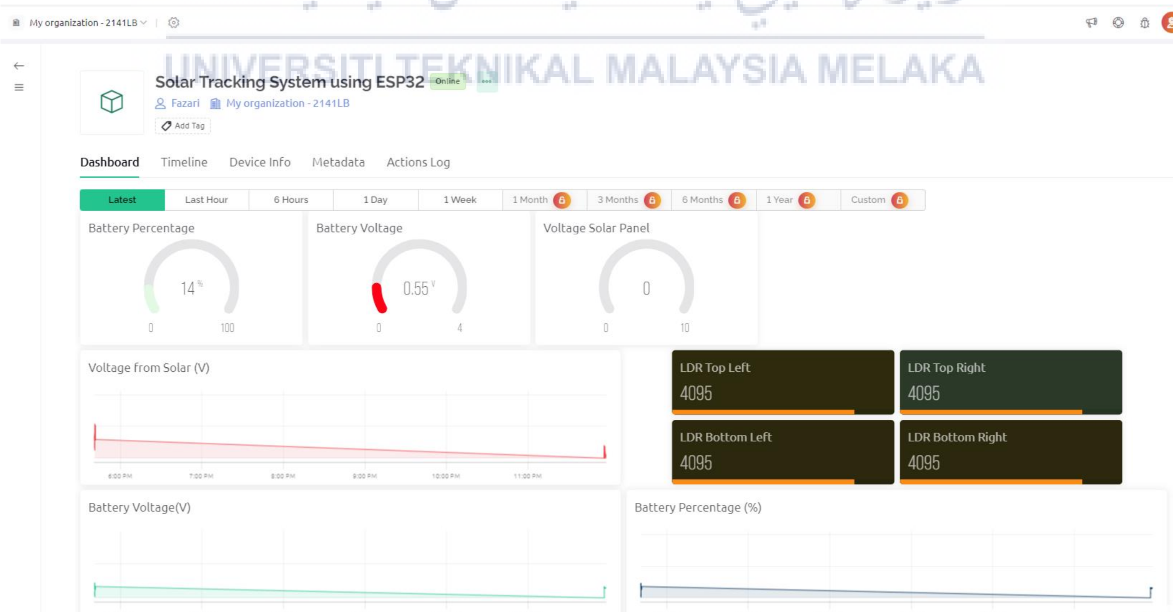

Figure 4.11 : Blynk Web Dashboard

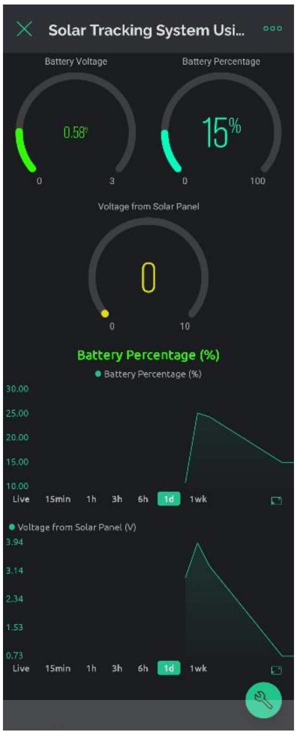

Figure 4.12 : Blynk Application Interface

Blynk's mobile app and web interface provide not only remote monitoring, but also an interactive control platform for the smart solar tracking system. Users can actively interact with the system via the app or website. This interactive element gives consumers a sense of control and involvement by allowing them to adapt the solar tracking system's behaviour to their specific needs. The seamless integration of Blynk's mobile and web interfaces transforms the solar tracking system into a user-centric, intelligent energy solution, providing a user-friendly experience that goes beyond traditional monitoring and empowers individuals to actively manage their sustainable energy production.

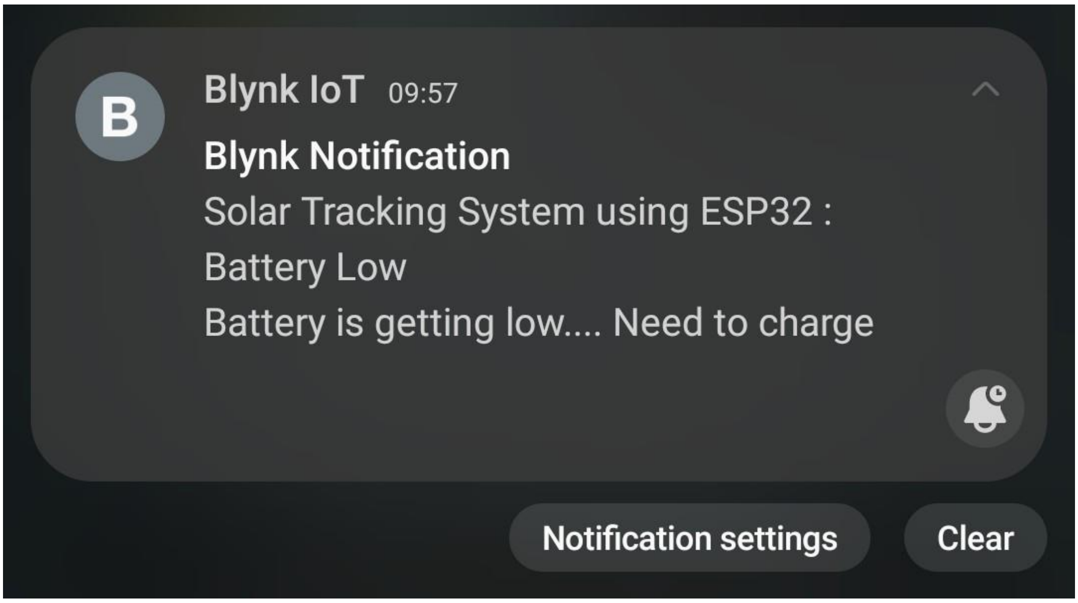

Figure 4.13 : Notification Alert on Smartphone

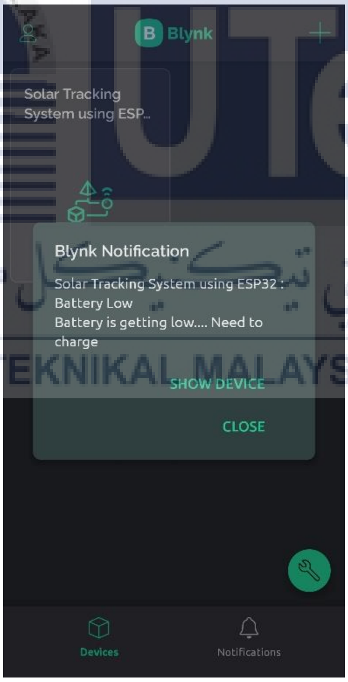

Figure 4.14 : In-app Notification Alert

The adoption of a Blynk-based notification system to inform smartphone users to a low battery state is a practical and user-friendly method for improving device management. When it falls below a 30% battery percentage, a notification is easily transmitted to the user's smartphone as shown in figure 4.13 and figure 4.14. This integration guarantees that consumers receive timely alerts indicating that the device's battery is running low and needs to be recharged. The Blynk app acts as a centralised hub for users to not only get notifications, but also monitor and control their connected devices remotely, resulting in a more simplified and user-friendly experience. This notification system dramatically enhances user awareness and response, avoiding unexpected disruptions caused by a drained battery.

4.3 Summary

In this section, an IoT-based smart solar tracking system was built with NodeMCU and the Blynk app. The data and analysis revealed the system's effectiveness in optimising power generation through real-time monitoring of important solar panel characteristics. Voltage levels were monitored at various times of solar exposure using Blynk and IoT-enabled sensors, allowing to compare a static solar system to a solar tracking system. The sun tracking system regularly beat the static system in terms of voltage, current, and power output. Furthermore, the integration of Blynk not only provided a user-friendly interface for real-time monitoring but also enabled interactive control through both mobile and web interfaces. The system's hardware and software components, as well as the Blynk notification feature, were shown, demonstrating the effective implementation of an intelligent solar tracking solution that increased user engagement and efficiency.

CHAPTER 5

CONCLUSIONS AND RECOMENDATIONS

5.1 Conclusions

As a conclusion, this project intends to overcome the issues associated with static solar panels by creating an intelligent solar tracking system that is coupled with IoT technology and operated via the Blynk app. The background focuses on the growth of the solar panel business, emphasising the significance of technological advancements and smart solutions in improving efficiency and sustainability.

The problem statement describes the inefficiency of static solar panels in capturing maximum sunlight, resulting in energy waste. The proposed method entails developing a sophisticated solar tracking system capable of dynamically altering the location of solar panels to match the sun's movement throughout the day. The use of IoT and the Blynk app allows for remote monitoring and control, making the system suited for tough or remote settings.

The project's goals centre on the design, development, and efficiency testing of the smart solar tracking system. The device actively tracks the sun in order to maximise solar energy absorption, contributing to a more sustainable and environmentally friendly energy option. The project includes the integration of ESP32, servo motors, and sun-tracking devices to create an effective solar tracking system. The system supports real-time monitoring, control via the Blynk app, and proactive maintenance notifications.

The intended outcomes include demonstrating the effectiveness of the smart solar tracking system as compared to static solar panels. This is intended to highlight the significant benefits of sun-tracking technology in maximising electricity generation. The system's capacity to adapt to the sun's location throughout the day results in a higher energy output than stationary solar panels.

In summary, In conclusion, the invention of this advanced solar tracking system not only addresses the current limits of static solar panels, but also makes a substantial contribution to increasing solar energy utilisation. By advocating a more effective and intelligent approach to harnessing solar electricity, the project contributes to the larger goals of reducing dependency on fossil fuels and lessening the impact of climate change, providing both economic and environmental benefits.

5.2 Future Works Recommendations

As with every new initiative, there is room for improvement and growth to maximise the capabilities and impact of the designed smart solar tracking system. This section provides numerous proposals for future work that can help the project's continuous development and refinement.

5.2.1 Battery Upgrade

Upgrading the current 3.7V lithium-ion battery to a higher capacity and voltage type. This upgrade intends to increase the system's energy storage capacity, ensuring consistent power availability during periods of low sunlight. A larger battery improves energy autonomy and contributes to a more dependable power source. This optimization enhances the overall storage capacity, allowing the system to efficiently store excess energy for use during periods of low sunlight or high energy demand.

5.2.2 Inverter Improvement

Consider upgrading the inverter technology from the existing TP4056 to a more modern model. This modification aims to improve energy conversion efficiency and stability. A better inverter optimises the conversion of direct current (DC) from solar panels to alternating current (AC), decreasing energy losses during conversion and distribution.

5.2.3 Motor Enhancement

Upgrading the motor system to something more powerful and efficient, such as stepper motors. This upgrade aims to improve the precision and responsiveness of solar panel positioning. A more improved motor system guarantees that the panels precisely monitor the sun's movement, maximising solar absorption and total system efficiency.

5.2.4 Larger Solar Panel Integration

Larger solar panels with a higher input rating are recommended to improve the system's energy capture capability. Larger panels provide more surface area for solar absorption, resulting in higher electrical production. This upgrade directly improves the system's ability to generate more power and optimise solar energy utilisation.

5.2.5 Cut Off Mode for Battery Management

Implementing a cut-off mode for battery management is critical to safety and longevity. When the battery reaches full charge, the system should automatically disconnect from the charging source to avoid overcharging. This protection feature maintains the battery's health and reduces the hazards connected with overcharging.

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```
#include <ESP32Servo.h>
#define BLYNK_TEMPLATE_ID "TMPL6PFk9pfnV"
#define BLYNK_TEMPLATE_NAME "Solar Tracking System using ESP32"

#define BLYNK_FIRMWARE_VERSION        "0.1.0"

#define BLYNK_PRINT Serial
//#define BLYNK_DEBUG

#define APP_DEBUG

#define USE_ESP32_DEV_MODULE
#include "BlynkEdgent.h"


int batvolt=39;   // Check Battery voltage
float voltage;
int bat_percentage;
int sensorValue;
float calibration = 0.40;

int solarpin = 36;  // Check Solar voltage
float in_voltage ;
float adc_voltage ;
float R1 = 30000.0;
float R2 = 7500.0;
float ref_voltage = 5.0;
int adc_value ;

Servo servoh; //Servo declare
Servo servov;

int ldr_lu = 34; //LDR left up
int ldr_ru = 35; //LDR right up
int ldr_ld = 32; //LDR left bottom
int ldr_rd = 33; //LDR right bottom
int servo_h = 25; //servo horizontal
int servo_v = 26; //servo vertical
int hpos;
int vpos;
int servo_max = 178; // maximum position for servo
int servo_min = 2;   // minimum position for servo
```


System Coding page 1

```
#include <LiquidCrystal_I2C.h>  //LCD display
int lcdColumns = 16;
int lcdRows = 2;
LiquidCrystal_I2C lcd(0x27, lcdColumns, lcdRows);
String messagebat ;
String messagesolar ;

void setup()
{
  Serial.begin(115200);
  delay(100);

  pinMode(batvolt,INPUT);
  pinMode(solarpin,INPUT);
  servoh.attach(servo_h);
  servov.attach(servo_v);

  servoh.write(-90); //initial position before connect wifi
  servov.write(0);
  delay(3000);
  servoh.write(90);
  servov.write(0);

  lcd.init();
  lcd.backlight();

  BlynkEdgent.begin(); //blynk connect wifi
}

void loop() {
  Serial.println();
  Serial.println("--------------------------------------------------------------------");
  BlynkEdgent.run();
  solarTracking();

  adc_value = analogRead(solarpin);     //SOLAR
  adc_voltage  = (adc_value * ref_voltage) / 1024.0;
  in_voltage = adc_voltage ;

      //send data to blynk
    Blynk.virtualWrite(V2, in_voltage);  // for solar voltage

  sensorValue = analogRead(batvolt);  //BATTERY
  voltage = (((sensorValue * 3.7) / 4095));
  bat_percentage = mapfloat(voltage, 0, 3.7, 0, 100);
  Blynk.virtualWrite(V3, voltage);  // for battery voltage
  Blynk.virtualWrite(V4, bat_percentage);  // for battery percentage
```


System Coding page 2

```
Serial.print("   Analog Bat Value = ");
  Serial.print(sensorValue);
  Serial.print("    Battery Voltage = ");
  Serial.print(voltage);
  Serial.print("    Battery Percentage = ");
  Serial.print(bat_percentage);
  Serial.print("%");
  Serial.print("    Solar Voltage = ");
  Serial.print(in_voltage, 2);
  Serial.print("    adc Voltage = ");
  Serial.print(adc_value, 2);
  Serial.print("    adc bat = ");
  Serial.print(sensorValue, 2);

  displayOnLCD();


      if (bat_percentage <=30)  //send notification on phone
    {
      Blynk.logEvent("battery_low", "Battery is getting low.... Need to charge") ;
    }

Serial.println();
Serial.println("--------------------------------------------------------------------------");

}


float mapfloat(float x, float in_min, float in_max, float out_min, float out_max)
{
  return (x - in_min) * (out_max - out_min) / (in_max - in_min) + out_min;
}

void solarTracking() //tracking system
{
  double ldrStatusLU = analogRead(ldr_lu);
  double ldrStatusRU = analogRead(ldr_ru);
  double ldrStatusLD = analogRead(ldr_ld);
  double ldrStatusRD = analogRead(ldr_rd);

    Blynk.virtualWrite(V5, ldrStatusLU);  //send light data to blynk
    Blynk.virtualWrite(V6, ldrStatusRU);
    Blynk.virtualWrite(V7, ldrStatusLD);
    Blynk.virtualWrite(V8, ldrStatusRD);
```

System Coding page 3

```
Serial.print("--LDRLU Status: ");  //display serial monitor
  Serial.print(ldrStatusLU);
  Serial.print("   LDRRU Status: ");
  Serial.print(ldrStatusRU);
  Serial.print("   LDRLD Status: ");
  Serial.print(ldrStatusLD);
  Serial.print("   LDRRD Status: ");
  Serial.print(ldrStatusRD);
  Serial.print("       HoriPos: ");
  Serial.print(hpos);
  Serial.print("       VertiPos: ");
  Serial.print(vpos);
  Serial.print(" -- ");
  Serial.println();

  if ((ldrStatusLU < 3500) || (ldrStatusLD < 3500)) //move left
  {
    hpos -= 1;
    servoh.write(hpos);
  }

  if ((ldrStatusRU < 3500) || (ldrStatusRD < 3500)) //move right
  {
    hpos += 1;
    servoh.write(hpos);
  }

  if ((ldrStatusRU < 3500) || (ldrStatusLU < 3500)) //move up
  {
    vpos += 1;
    servov.write(vpos);
  }

  if ((ldrStatusRD < 3500) || (ldrStatusLD < 3500)) //move down
  {
    vpos -= 1;
    servov.write(vpos);
  }

  if ((ldrStatusLU > 3800) && (ldrStatusRU > 3800) && (ldrStatusLD > 3800) &&
(ldrStatusRD > 3800)) //no light detect
  {delay(200);
    hpos = 90;  //move to initial position
    vpos = 90;
    servoh.write(hpos);
    servov.write(vpos);
  }
}
```

System Coding page 4

```
void displayOnLCD() {
  lcd.setCursor(0, 0);
  messagebat = "Battery: " + String(bat_percentage) + " %" ;  //display battery
percentage
  lcd.print(messagebat);

  lcd.setCursor(0, 1);
  messagesolar = "VoltSolar: " + String(in_voltage, 2) + "V"; //display voltage from
solar
  lcd.print(messagesolar);
}
```

System Coding page 5