DEVELOPMENT OF IOT BASED SOLAR GRASS CUTTING ROBOT USING NODEMCU ESP32 AND BLYNK APPLICATION

MUHAMMAD MUIZZUDIN BIN ZAKARIA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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MUHAMMAD MUIZZUDIN BIN ZAKARIA

This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours

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RAFIHAH BINTI MOHD ZAIN
Jurutera Pengajar
Jabatan Teknologi Kejuruteraan
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Elektronik dan komputer (FTKEK)
Universiti Teknikal Malaysia Melaka

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DEDICATION

This thesis is dedicated to those who help me from the beginning until finish of the project's development, To my beloved mother, father, and family Also, My supervisor My lecturer and All my fellow friends. Thank you for all the guidance support and encouragement up to this point.

ABSTRACT

The creation of an ecologically friendly and energy-efficient grass-cutting robot is the primary objective of this project. It will be an intelligent and user-friendly gadget that runs on solar energy and makes use of cutting-edge IoT technology and mobile application control. The first objective of the project is to design a grass cutter that reduces energy consumption by using solar panels, thus minimizing reliance on conventional electricity sources. This not only lowers operational costs but also contributes to environmental conservation efforts by reducing the carbon footprint.Next objective focuses on enhancing user convenience and control. By using the NodeMCU ESP32 microcontroller and the Blynk application, the grass cutter robot can be easily monitored and operated remotely via a mobile device. This feature is particularly beneficial for users with physical impairments and elderly individuals, offering them a seamless and effortless gardening experience. Lastly, the project aims to deliver a smart grass cutter that operates without producing air pollutants, ensuring a cleaner and healthier environment. In conclusion, this project presents a new approach to lawn care by combining solar energy utilization, IoT technology, and user-centric design to create an efficient, eco-friendly, and accessible grass-cutting robot.

ABSTRAK

Penciptaan robot pemotong rumput yang mesra ekologi dan cekap tenaga adalah objektif utama projek ini. Ia akan menjadi alat pintar dan mesra pengguna yang menggunakan tenaga suria dan menggunakan teknologi IoT termaju dan kawalan aplikasi mudah alih. Objektif pertama projek ini adalah untuk bentuk pemotong rumput yang mengurangkan penggunaan tenaga dengan menggunakan panel solar, sekali gus meminimumkan pergantungan kepada sumber elektrik konvensional. Ini bukan sahaja mengurangkan kos operasi tetapi juga menyumbang kepada usaha pemuliharaan alam sekitar dengan mengurangkan jejak karbon. Objektif seterusnya menumpukan pada meningkatkan kemudahan dan kawalan pengguna. Dengan menggunakan mikropengawal NodeMCU ESP32 dan aplikasi Blynk, robot pemotong rumput boleh dipantau dan dikendalikan dari jauh dengan mudah melalui peranti mudah alih. Ciri ini amat bermanfaat untuk pengguna yang mengalami kecacatan fizikal dan individu warga emas, menawarkan mereka pengalaman berkebun yang lancar dan mudah. Akhir sekali, projek ini bertujuan untuk menyampaikan pemotong rumput pintar yang beroperasi tanpa menghasilkan bahan pencemar udara, memastikan persekitaran yang lebih bersih dan sihat. Kesimpulannya, projek ini mempersembahkan pendekatan baharu kepada penjagaan rumput dengan menggabungkan penggunaan tenaga suria, teknologi IoT, dan reka bentuk tertumpu pengguna untuk mencipta robot pemotong rumput yang cekap, mesra alam dan boleh diakses.

ACKNOWLEDGEMENT

I want to express my deep gratitude to everyone who contributed to the successful completion of my final year project, ”Development of IoT-Based Smart Solar Grass Cutting Robot Using NodeMCU ESP32 and Blynk Application.” First and foremost, I would like to thank my project supervisor, Madam Raeihah binti Mohd Zain from the Faculty of Technology Electronic And Computer Engineering at Universiti Teknikal Malaysia Melaka, for their invaluable guidance, support, and encouragement throughout this project. I would like to extend my appreciation to my classmates and friends for their continuous support, motivation, and constructive feedback. Their collaboration and camaraderie have made this journey enjoyable and enriching. Furthermore, I would like to acknowledge my family for their unwavering support and understanding. Their encouragement and belief in my abilities have been a constant source of strength and motivation. Lastly, I would like to thank the developers of the NodeMCU ESP32 and Blynk applications for providing the tools and platforms that made this project possible. Their contributions to the open-source community have significantly facilitated the development of IoT projects like mine. Thank you all support and contribution to this project. This achievement would not have been possible without you.

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LIST OF ABBREVIATIONS

IoT	-	Internet of Things.
PID	-	Proportional Integral Derivative.
DC	-	Direct Current.
LCD	-	Liquid Crystal Display.
GPI/O	-	General-Purpose Input/Output.
I2C	-	Inter-Integrated Circuit.
NodeMCU	-	Node MicroController Unit.
SRAM	-	Static Random Access Memory
WPA	-	Wi-Fi Protected Access
GHz	-	Gigahertz
BLE	-	Bluetooth Low Energy
BR/EDR	-	Bluetooth Basic Rate/Enhanced Data Rate
STA/AP	-	Stations and Access Points
PWM	-	Pulse Width Modulation
COM	-	Common
GND	-	Ground
VCC	-	Common Collector Voltage
USB	-	Universal Serial Bus
IDE	-	Integrated Drive Electronics

CHAPTER 1

INTRODUCTION

This chapter describes the project background, problem statement, objectives, and scope of work in developing IoT based solar grass cutting robot using NodeMCU ESP32 and Blynk application.

1.1 Background

In the past, maintaining lawns needed labor-intensive physical labour or simple mechanical instruments, which frequently proved to be time-consuming. However, the field of lawn care has changed as a result of the development of IoT technology. Grass cutters have become ”smart” machines due to manufacturers’ integration of these features, which enable remote monitoring and control.

However, the creativity does not end there. Its can use solar energy to run on a sustainable basis, minimising its carbon footprint and maintaining continuous operation. The brains behind the operation are the NodeMCU ESP32, which allows for smooth communication between the robot and the Blynk application.Users have total control over their lawn care experience with the Blynk application. From the palm of user, they can control the robot’s cutting parameters, plan maintenance intervals, and track its advancement in real time. It has never been simpler to take care the lawn, whether at home or halfway across the globe.

1.2 Problem Statement

Finding time for lawn care in today's hectic environment is difficult, which can result in overgrown yards and even fines. Then, nowadays grass cutting machine make home-owners take longer time to maintain lawn care. Next, the usage of fossil fuels in the production process and the use of typical lawn mowers both add to pollution. Last but not least, manual lawn care is physically taxing for people with impairments or old people.

1.3 Project Objectives

The main aim of this project are:

1. To develop an energy saving grass cutter that can be powered by solar energy as its primary power source and air pollution free and user friendly.
2. To design a grass cutter robot that can be controlled and monitored using mobile application.
3. To analyse the energy efficiency of solar panel and optimal time utilization of the grass cutter robot.

1.4 Scope of Project

This project focuses on using the Internet of Thing or Wi-Fi module through the smartphone to control the grass cutter robot. This project system uses solar energy as its primary power source. It uses 12V batteries to power the bot movement motors as well as the grass cutter motor. The batteries are charged using a solar panel. This project uses NodeMCU ESP32 as a main microcontroller. The NodeMCU ESP32 will receive the signal from smartphone and transmit data to dc motor grass motor and tyre.

1.5 Innovative IoT-Based Solar Grass-Cutting Robot

The project aims to create a solar-powered IoT-based grass-cutting robot that addresses critical societal and global challenges like environmental conservation and energy efficiency. By using solar power as its primary energy source, the robot decreases its dependency on fossil fuels, which contribute considerably to global greenhouse gas emissions. This method not only reduces carbon footprint but also supports worldwide efforts to battle climate change and transition to sustainable energy systems. Incorporating solar energy into the architecture indicates an environmentally conscious approach to technology, supporting a cleaner, more sustainable future.

The project focusses accessibility and inclusive by addressing the needs of people with physical disabilities and the elderly. The robot has a user-friendly design enabled by IoT technology and mobile app control, ensuring ease of operation and remote access. This design encourages independence for people who may find traditional manual lawn care difficult, exhibiting a dedication to providing solutions that benefit a varied community. By improving usability for these populations, the project connects with global goals of eliminating inequities and improving quality of life.

One of the project's most significant achievements is its emphasis on pollution reduction. Unlike ordinary gas-powered lawn mowers, which produce pollutants, this robotic mower generates no air or noise pollution. This makes it excellent for environmentally sensitive settings like hospitals, schools, and residential areas. By reducing both environmental effect and noise, the project offers a cleaner and quieter way to maintain green spaces, ultimately contributing to healthier living conditions.

Finally, the project's use of advanced IoT technology together with renewable energy demonstrates its connection with present technical trends and innovation. The NodeMCU ESP32 microcontroller and Blynk mobile application allow for seamless monitoring and control, showcasing how smart technology may alter ordinary tools. This forward-thinking approach not only improves user comfort, but it also promotes the use of sustainable and smart practices in everyday life. The initiative demonstrates how technology may address global concerns while also enhancing local living standards.

CHAPTER 2

LITERATURE REVIEW

This chapter provides a broad overview of the project related to the topic in this report. Besides, the relevant literature is critically discussed and presented later in this chapter.

2.1 Introduction

The current transformation in conventional processes has resulted in enhanced automation, convenience, and efficiency from the integration of Internet of Things (IoT) technologies across numerous areas. The Internet of Things smart grass cutter is one example of an application that makes use of automation, sensors, and connectivity to improve lawn care procedures. The purpose of this review of the literature is to investigate current studies, innovations, and technological breakthroughs in IoT smart lawn cutters.

2.2 Past Related Project Research

2.2.1 Automated Solar Based Electric Grass Cutter with Multi-Purpose Robotic Vehicle

"Automated Solar-Based Electric Grass Cutter with MultiPurpose Robotic Vehicle" is a battery-operated device designed to efficiently perform grass cutting. This innovative system includes an automated grass cutter integrated into a four-wheeled robotic vehicle equipped with an Arduino UNO Microcontroller, using ultrasonic sensors to detect obstacles and respond accordingly. A customized blade is used to cut hard, thick shrubs, while a nylon strip is employed to cut thin grass approximately 1 inch thick. Additionally, the project incorporates a solar panel to charge the batteries. Figure 2.1 shows the block diagram of the project

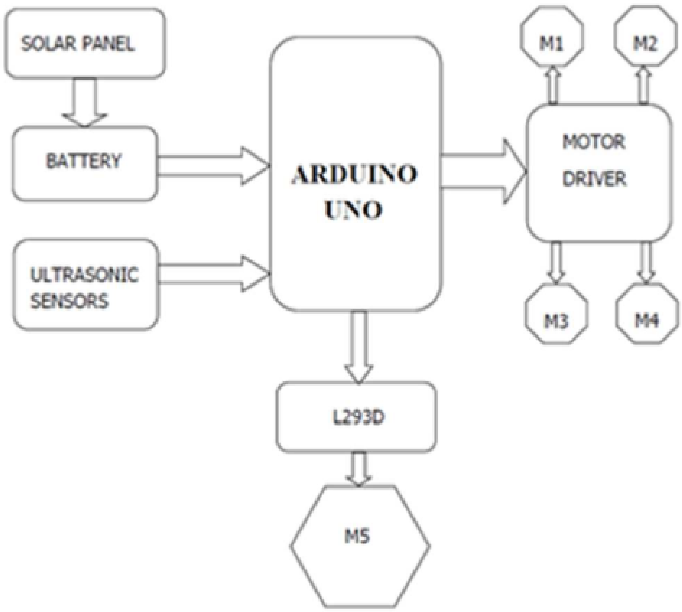

Figure 2.1: Block diagram of the proposed system.

2.2.2 Solar Grass Cutter with Water Spraying Vehicle

Ramya *et al.*, [2] describes the design of a solar-powered grass cutter with a water spraying system using RF technology. It aims to perform grass cutting and water spraying simultaneously. The design harnesses solar energy using PV panels and stores it in a 12V rechargeable DC battery. The vehicle can perform two operations controlled by a switch: grass cutting using a DC motor and water spraying using a water pump. The RF module, operating at 434 MHz, controls all the motors wirelessly using an encoder/decoder pair. Figure 2.2 shows the block diagram of the proposed method.

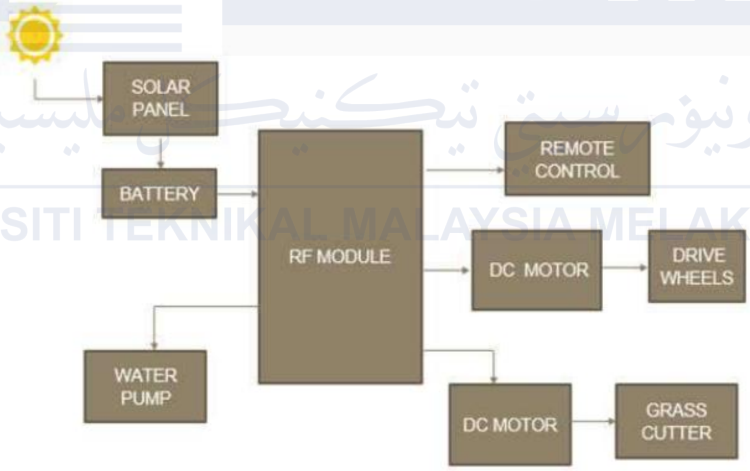

Figure 2.2: System Block Diagram.

2.2.3 Solar Based Grass Cutter Robot

In a recent proposed system, Balaganesan *et al.*, [3] introduces a solar-powered grass cutter, harnessing renewable solar energy for efficient grass cutting. The cutter, comprising a motor, blade, frame, wheels, and solar panels, has been rigorously tested for performance, demonstrating its effectiveness and comparable cutting ability to traditional grass cutters. Moreover, by utilizing solar energy, this grass cutter significantly reduces environmental impact by eliminating greenhouse gas emissions and minimizing noise pollution. This pioneering project underscores the feasibility and advantages of employing solar power for grass cutting, offering a promising solution for more sustainable and environmentally friendly lawn maintenance practices. Figure 2.3 shows the block diagram of the proposed system.

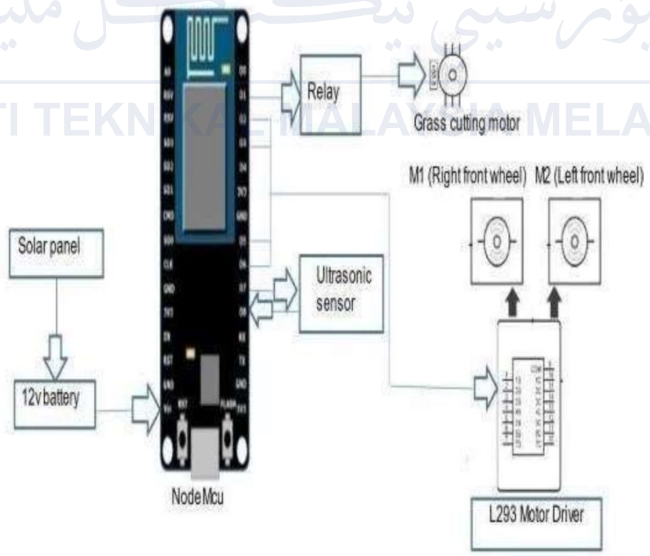

Figure 2.3: Block Diagram of the System.

2.2.4 Solar Powered Bluetooth Controlled Grass Cutting Robot

In this project, Athipatla *et al.*, [4] had create an autonomous robotic lawnmower that can be operated using an Android device. The Arduino UNO board is connected to the phone via a Bluetooth module. Previously, lawnmowers required expensive fuel to function. However, in this project it use a solar panel to recharge the battery, eliminating the need for an additional power source. Solar energy is a more convenient and cost-effective alternative to other energy sources. Figure 2.4 shows that the input and output of the proposed system.

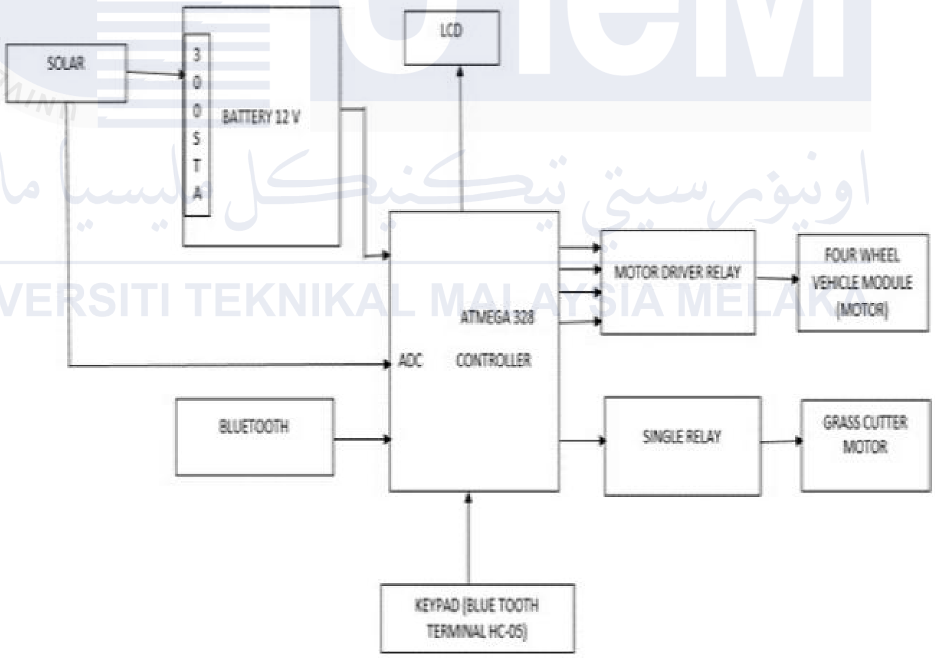

Figure 2.4: Block Diagram of System.

By using solar panels, it can harness the sun's energy to generate free power. The solar panel charges the battery, which in turn powers the lawnmower. The entire operation of the machine is controlled through an Android application. The Arduino UNO serves as the controller of the system. It can communicate with a Bluetooth module and DC motors through various connections. The DC motor of the solar grass cutter is controlled by an Arduino UNO, which receives data from an Android app via a Bluetooth module. Additionally, an ultrasonic obstacle detector is connected as an input. When an obstacle is detected, the machine is halted, and the sensor's data is sent to the cloud.

2.2.5 Design and Development of Grass Cutter using Solar Renewable Energy Source

In this proposed method Kumar *et al.*, [5] had involves designing a solar-powered grass-cutting robot that runs on solar energy and is able to avoid obstacles. By using solar energy as the primary power source, the need for electricity and fuel is eliminated. The grass-cutting blade is connected to a DC motor, while a Battery Operated (BO) motor controls the direction of the cutter. These motors and the energy from the solar panel are connected to the NodeMCU microcontroller. This robot is designed to perform specific tasks with minimal human intervention, ensuring high accuracy and precision. The system operates based on the working principle of a grass cutter robot, requiring minimal human intervention and delivering high accuracy in its application. Additionally, the grass cutter robot can be controlled from all directions with the help of the Internet of Things (IoT). Figure 2.5 shows the block diagram of the proposed method.

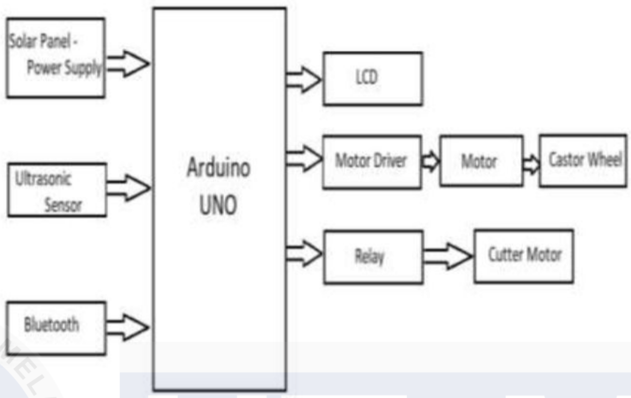

Figure 2.5: Block diagram of solar grass cutter system.

2.2.6 PID Controller Based Automatic Solar Power-Driven Grass Cutting Machine

An automatic grass cutting machine has been designed and implemented by Habib *et al.*, [6]. This method focus on utilizing solar energy as its primary power source. The grass cutter is lightweight, portable, and consists of two main parts: a motor-powered base and cutting blades with a motor. By default, the grass cutter operates automatically, but it can also be manually operated if needed. It detects the position of the grass using a color sensor that recognizes a specific band of green color signals and moves automatically towards the grass with its motorized controlled base. When the motor-driven cutting blade approaches the grass, it begins cutting and continues until all surrounding grass is cut down. The prototype of the grass cutter has been tested experimentally, and the test results confirm that it successfully performs its operation. Additionally, two degree-of-freedom PID controllers are proposed to control the motor speed of the prototype. Figure 2.6 shows the flowchart of the proposed method.

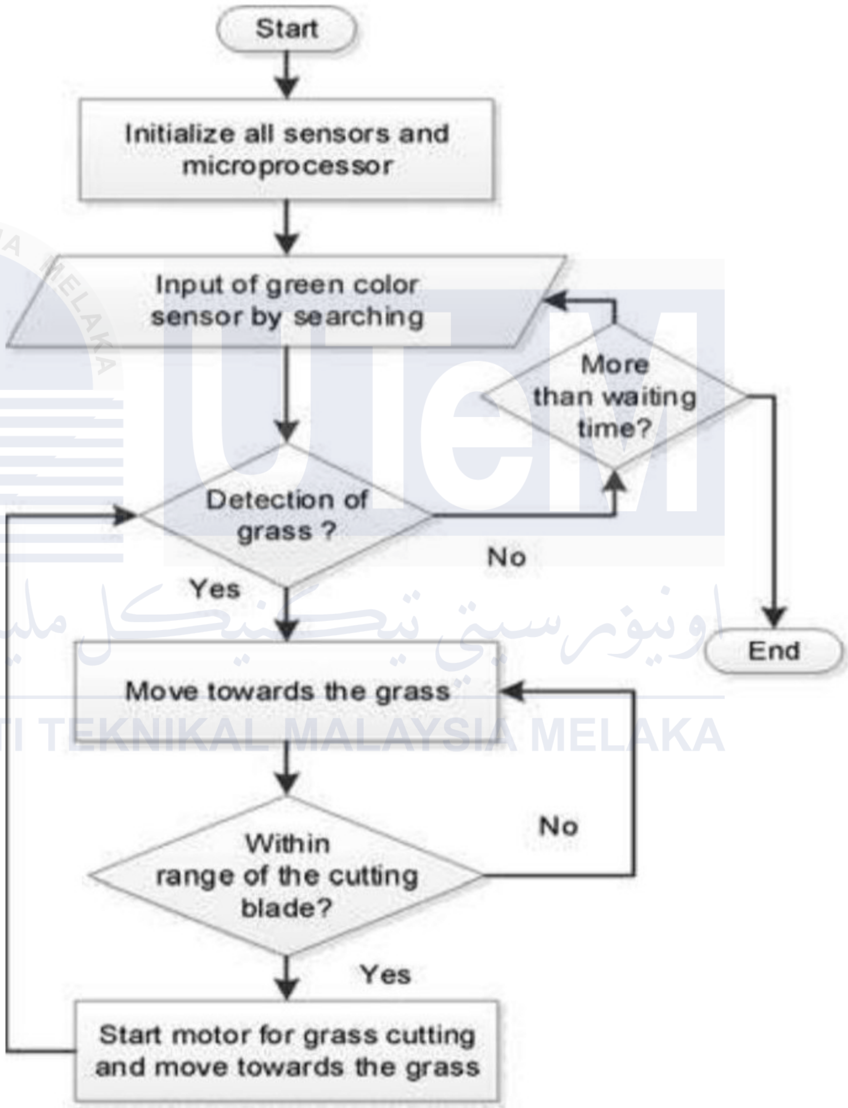

Figure 2.6: Flow chart of the project system.

2.2.7 Bluetooth Controlled Green Sward Cutter Using IoT

Aditya *et al.*, [7] have introduces a new IoT-enabled movable grass cutting system that includes real-time camera access and remote-control capabilities through a smartphone app. The Bluetooth-controlled Green Sward cutter system improves the convenience and efficiency of grass cutting processes and assists farmers in agriculture. The system consists of a grass cutter equipped with IT modules, including an Arduino UNO board as the main controller, an ESP32 CAM module for real-time monitoring, a HC-05 module for wireless connection, linear and adjustable blades for cutting the grass, and motor drivers for the wheels of the robot as well as for the blades. The camera module enables users to monitor the cutting progress remotely and ensure precise operation. The integration of IoT, camera access, and smartphone remote control enhances the efficiency, convenience, and user experience of grass cutter maintenance. Figure 2.7 shows the block diagram of proposed method.

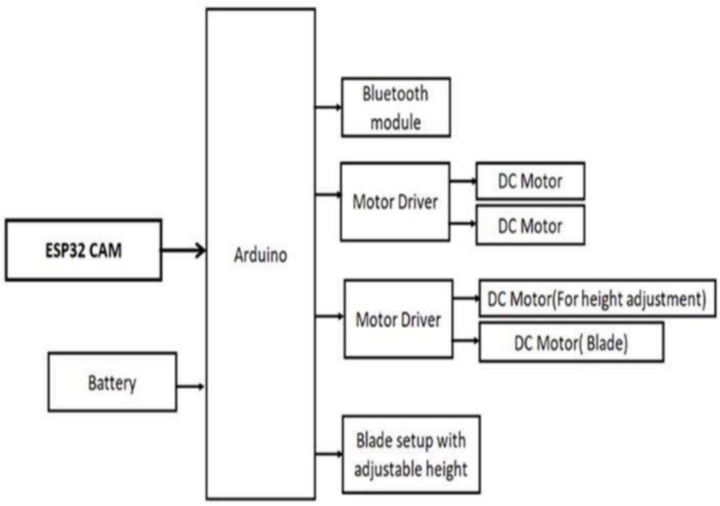

Figure 2.7: Block diagram of green sward cutter system.

2.2.8 Electrical Energy-Powered Grass Cutter with Autonomous Operation and Pollution Mitigation

In this study Arunkumar *et al.*, [8]presents a new approach to solving these problems by creating an electrically powered lawn mower that prioritizes environmental sustainability and economic feasibility. The key technology behind this innovation is a microcontroller system, which allows for precise control of the lawn mower's various functions. Additionally, the lawn mower is equipped with obstacle sensors, ensuring independent operation and obstacle detection. This autonomous feature simplifies operation, removing the need for skilled personnel to operate the machine. The incorporation of autonomous operation and obstacle detection also enhances safety and usability. Figure 2.8 shows that the input and output of the proposed system.

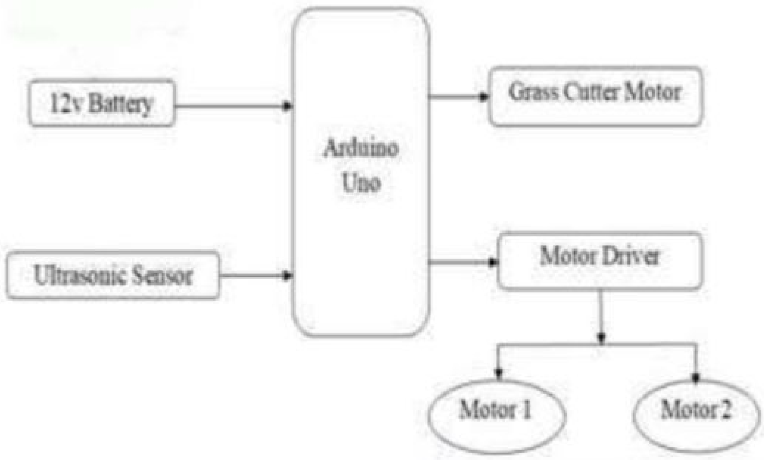

Figure 2.8: Block Diagram of the proposed system.

2.2.9 Automation Solar Powered Grass Cutter Incorporated with Alphabet Printing and Pesticide Sprayer

In this proposed system Manimegalai *et al.*, [9]aims to enhance the design of traditional lawn mowers and improve the capabilities of standard robotic lawn mowers, while ensuring cost efficiency. The self-propelling lawn mower design includes remote control and autonomous capability, making it user-friendly for most consumers. It is safe and efficient as it is electric-powered and cordless. The paper suggests that the self-propelling electric robotic lawn mower is environmentally friendly. Figure 2.9 shows detail about block diagram of the proposed system.

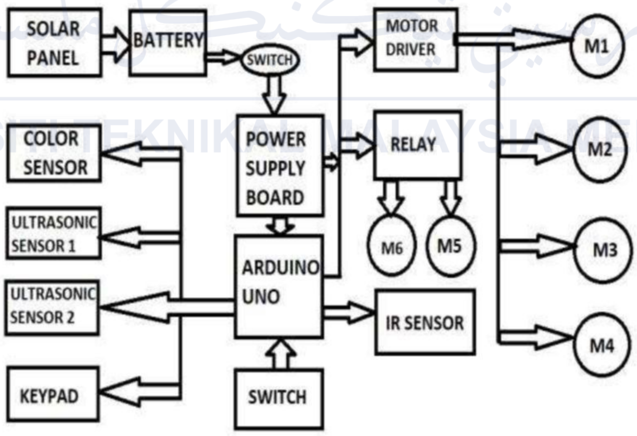

Figure 2.9: The block diagram of the system.

However, the grass cutter's engine produces a significant amount of noise, leading to noise pollution. As a result, it cannot be used in silent zones such as hospitals, educational institutions, and courts. To address this issue, the machine should be designed to reduce noise so that it can be used in silent zone areas. The machine moves quickly on the ground and grass. The deck adheres to all current safety standards, featuring a moving flap that opens in case of long grass and closes to prevent objects from being thrown out of the machine's path.

2.2.10 Design and Implementation of IoT Enabled Grass Cutting Robot Powered by Solar PV System

For this proposed method, Mohan *et al.*, [10] aims to create a solar-powered grass-cutting robot that runs on solar energy and is capable of navigating around obstacles. The robot uses solar energy as its primary power source, eliminating the need for electricity or fuel. A DC motor is used to drive the cutting blade, while a Battery Operated (BO) motor controls the direction of the cutter. These motors and the energy from the solar panel are connected to the NodeMCU microcontroller. Figure 2.10 shows detail about block diagram of the proposed system.

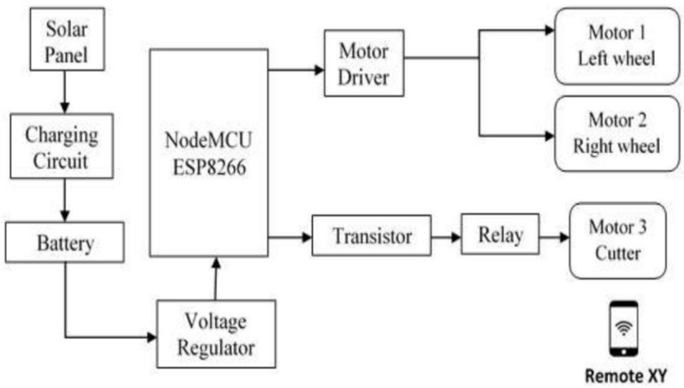

Figure 2.10: Proposed Model Block Diagram.

The robot's wheels and the cutter's On/Off function are controlled by a mobile application called Remote XY, which is connected to the microcontroller's Wi-Fi network. A robot is a system that performs specific tasks with minimal human intervention, achieving high accuracy and precision. This proposed system is based on the working principle of a grass cutter robot, requiring minimal human intervention and operating with high accuracy. The grass cutter robot can be controlled in all directions using the Internet of Things (IoT). IoT facilitates connecting and operating the robot through mobile applications.

Table 2.1: Summary of the previously proposed techniques

Authors	Project Title	Advantage(s)	Disadvantage(s)
Sunanda *2024*, [1]	Automated Solar Based Electric Grass Cutter with Multi-Purpose Robotic Vehicle.	• This initiative promotes eco-friendliness and reduces its negative effects on the environment.. • Can be useful for elderly people to use grass cutter.	• It is expensive to implement in this project. • Users need technical expertise to assemble and configure these parts correctly.
Ramya *2021*, [2]	Solar Grass Cutter with Water Spraying Vehicle.	• Reduced ecological contamination. • Lower operational cost due to the use of solar energy.	• High initial setup costs. • The dependence on sunlight for charging the battery.
Balaganesan *2023*, [3]	Solar Based Grass Cutter Robot.	• Reduces greenhouse gas emissions and noise pollution. • Increased sustainability for the grass cutter.	• Grass cutter have a limited range and run-time. • Higher initial cost compared to traditional lawn mowers.
Athipatla *2023*, [4]	Solar Powered Bluetooth Controlled Grass Cutting Robot.	• Solar energy is easier to adopt and more cost-effective than other energy sources. • The robot can be controlled remotely via a Bluetooth connection to an Android app.	• Increase the overall cost and complexity of the system. • Unclear if it can provide a satisfactory grass cutting experience.
K *2022*, [5]	Design and Development of Grass Cutter using Solar Renewable Energy Source.	• Real-time monitoring of environmental parameters. • Solar panels provide a clean and sustainable energy source, reducing carbon emissions.	• Grass cutter not be suitable for cutting large or tall grass. • Grass cutter need regular maintenance to keep them running smoothly.

Continued from previous page . . .

Authors	Project Title	Advantage(s)	Disadvantage(s)
Habib *2019*, [6]	PID Controller Based Automatic Solar Power-Driven Grass Cutting Machine.	• It harness renewable solar energy. ensuring a constant supply during daylight hours.	• Operating during rainy seasons can be pretty challenging.
Aditya *2024*, [7]	Bluetooth Controlled Green Sward Cutter Using IoT	• User can monitor and control the grass cutter from smartphone. • These grass cutter has sensor that can analyse the height of grass .	• The range of controlling grass cutter is limited. • Regular maintenance and blade check can be difficult.
Arunkumar *2023*, [8]	Electrical Energy-Powered Grass Cutter with Autonomous Operation and Pollution Mitigation.	• Solar panel require minimal maintenance. • Reducing the need for manual intervention.	• It efficiency drops in cloudy or rainy weather. • The initial setup cost for solar powered grass cutter can be quite.
Manimegalai *2018*, [9]	Automation Solar Powered Grass Cutter Incorporated with Alphabet Printing and Pesticide Sprayer.	• The grass cutter is light weight. • Time consumption for cutting the grass is less.	• Not suitable for high grass. • Integrating solar panels with IoT device adds complexity to the design.
R *2023*, [10]	Design and Implementation of IoT Enabled Grass Cutting Robot Powered by Solar PV System.	• Reduce noise and air pollution. • Less human intervention.	• The battery storage capacity can limit the operation time. • The performance of the grass cutter not always predictable.

CHAPTER 3

METHODOLOGY

This chapter describes the methodology and design steps to develop IoT Based Solar Grass Cutting Robot using NodeMCU ESP32 and Blynk Application.

3.1 Introduction

The main project components will be covered in this part, along with the techniques and approaches used to make sure all project requirements were satisfied. This section explains the main components and offers a brief overview of the actions that must be followed. This section is crucial for figuring out whether the system functions as expected and whether the project step in this area is whether the system operates smoothly.

3.2 Description of Methodology

This project follows a methodology that consists of installing hardware, software, explanation about block diagram of the project, show the project flowchart and producing a report. To familiarise with the startup and get a grasp of the procedures. The process next stage is to identify the hardware and software components that will be used in the circuit's building and programming.The process of testing ensures that the programming and the circuit are functional. Additionally, it is imperative to identify simple fixes for any project-related issues.

3.3 Block Diagram

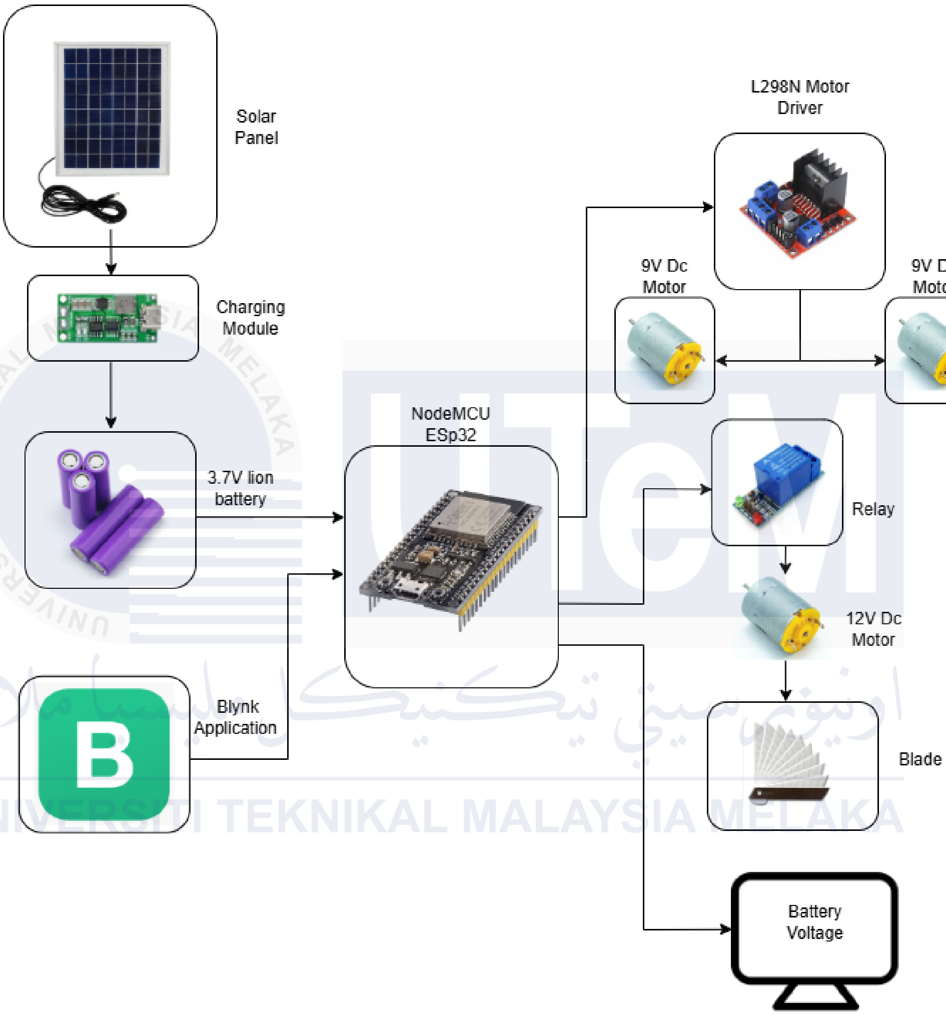

Figure 3.1: Block Diagram for IoT Based Smart Solar Grass Cutting Robot

Based on the figure 3.1 it show the outlines of a solar-powered grass cutting robot controlled via the Blynk application using a NodeMCU ESP32. For the input solar panel will be use for harnesses solar energy to power the rechargeable battery. Then, the battery stores the solar energy for consistent power supply. Next, Blynk application allows user interaction with the project. For the output, Blynk application will show voltage information to the user.

Then, DC Motors motors are present the wheels for movement, and the other operates the cutting blade. Lastly, the wheels enable the robot to move, and the blade performs the grass cutting. This smart system integrates renewable energy and mobile app control for efficient lawn maintenance.

3.4 Hardware

A table 3.3 containing the hardware used in the development is provided, detailing the quantity and cost of each component, along with the total cost.

Table 3.1: List of Hardware

No	Component	Price	Quantity	Total
1	NodeMCU ESP32	RM27.87	1	RM27.87
2	12V 3000RPM DC Motor	RM26.88	1	RM26.88
3	Solar Panel	RM34.00	1	RM34.00
4	Blade	RM1.88	1	RM5.00
5	3.7V 18650 LITHIUM-ION Battery	RM6.75	5	RM33.75
6	L298N Motor Driver	RM4.84	1	RM4.84
7	5V relay	RM3.50	1	RM3.50
8	9V 200RPM DC MOTOR	RM8.26	2	RM16.52
9	Multi-Cell 2S Type-C To 8.4V	RM3.95	1	RM3.95
10	Multi-Cell 3S Type-C To 12.6V	RM3.95	1	RM3.95
11	Total Spent			RM160.26

3.4.1 NodeMcu ESP32

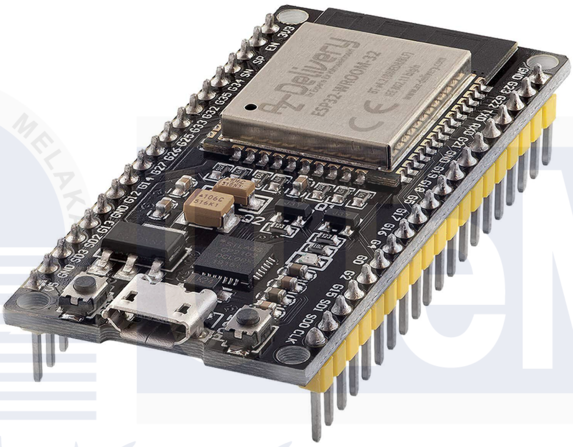

Figure 3.2: NodeMCU ESP32

Espressif Systems created the potent microcontroller known as the ESP32. It is the replacement for the well-known ESP8266. Compared to the single-core ESP8266, the ESP32 has a dual-core 32-bit CPU that allows for effective multitasking and better performance. Its integrated Bluetooth and Wi-Fi (2.4 GHz) capabilities are two of its most notable features. For Internet of Things (IoT) projects where connection is crucial, this makes it a great option. It can save programme code and other data on the 4 MB of flash memory that the ESP32 normally comes with.

The ESP32 also has more GPIO pins than the ESP8266. These pins enable the connection of different actuators, sensors, and project peripherals. Because of its high-resolution ADCs, the ESP32 is a good choice for applications that need precise analogue measurements. It may be used with a variety of power sources because it runs between 2.2 and 3.6 volts. Because of its breadboard-friendly compact factor, the NodeMCU ESP32 module makes development and prototyping easier. Finally, the USB micro B connector allows the user to power the ESP32 and conduct serial communication.

Table 3.2: Specification of NodeMCU ESP32

No	Specifications	Detail
1	Microcontroller	ESP32-D0WDQ6
2	Architecture	Xtensa 32-bit LX6 dual-core
3	Operating Voltage	3.3V
4	Flash Memory and SRAM	4MB and 520KB
5	Wi-Fi	802.11 b/g/n, dual-mode (STA/AP), WPA/WPA2, 2.4 GHz
6	Bluetooth	Bluetooth v4.2 BR/EDR and BLE
7	GPIO Pins	36 (multipurpose, configurable)
8	Dimensions	58mm x 31mm x 13mm

3.4.2 Solar Panel

Figure 3.3: Solar Panel

The 12V solar panel is composed of multiple photovoltaic cells, which are semiconductor devices that convert sunlight into direct current (DC) electricity. The cells are typically made from silicon-based materials and have a certain efficiency in converting sunlight into electricity. A standard 12V solar panel typically produces a voltage output of approximately 12 to 18 volts in direct sunlight, depending on its design and the number of solar cells connected in series.The actual voltage can vary based on environmental conditions, such as temperature and sunlight intensity.

The open circuit voltage is the voltage produced by the solar panel when it is not connected to any load. It is the maximum voltage the panel can generate. The maximum power point voltage is the voltage at which the solar panel generates the maximum power output. It is the voltage at which the solar panel operates most efficiently. The power rating of a 12V solar panel is typically specified in watts (W). It indicates the maximum power the panel can produce under standard test conditions (STC), which typically involve a sunlight intensity of 1000 watts per squaremeter and a temperature of 25°C.

3.4.3 L298N Motor Driver

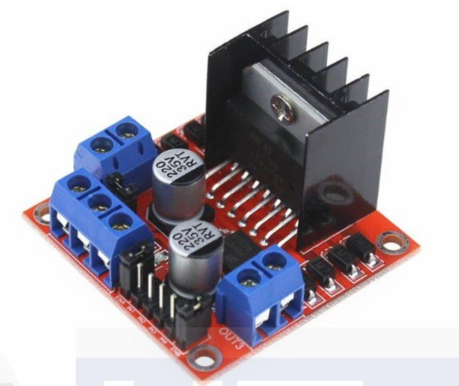

Figure 3.4: L298N Motor Driver

DC motors are controlled via the flexible L298N Motor Driver module. With its two H-bridges, the L298N can regulate two DC motors separately. Every H-bridge has the ability to operate a motor in both forward and backward directions. From 5V to 35V, the module can handle a broad variety of input voltages. Because of its adaptability, it works with many kinds of motors. It is appropriate for driving small to medium-sized motors since it can generate a peak current of up to 2A per motor. Pulse Width Modulation (PWM) is supported by the L298N for speed control. Smoothly changing the PWM signal allows you to change the motor speed.

The direction of each motor may be adjusted using the IN1/IN2 and IN3/IN4 pins. The user can move the motor forward or backward by adjusting these pins. For every motor, the L298N supplies a current sensing pin. This function allows the user to keep an eye on the motor current. For improved performance, certain L298N modules have a built-in heatsink to dissipate heat generated during motor operation.

3.4.4 DC Motor

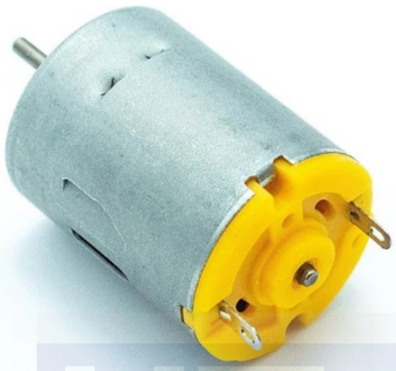

Figure 3.5: DC Motor

A DC motor transforms electrical energy from the input into mechanical energy at the output. It functions according to the Lorentz force principle, which is the force applied to a conductor that is conducting current in a magnetic field. The stator and the rotor are the two major parts of a DC motor. The motor's rotor, which rotates and houses the armature windings, is separate from the stator, which is the stationary portion that houses the field windings. The field windings produce a magnetic field that interacts with the armature windings' magnetic field when an electric current is delivered to them. In order to rotate and transform the DC energy into mechanical energy, this interacts with the rotor. In this project, there are 3 DC motor that will be use, 2 of it will be use to control the project and 1 of it is use for the rotation of blade.

3.4.5 12V Relay

Figure 3.6: 12V Relay

A relay is an electrically operated switch that can be turned on or off. It allows you to control high-voltage devices using a low-voltage signal from a NodeMCU ESP32. When activated, the relay electromagnet pulls to either open or close an electrical circuit. The relay has two main sides, the high-voltage side and the low-voltage side. High-voltage side it connects to the mains voltage. It has three sockets which is, Common (COM), Normally Closed (NC) and Normally Open (NO). COM is the common pin. Meanwhile, NC pin will make the relay closed by default then allowing current flow unless it receive a signal to open the circuit. For NO pin The relay is open by default and the circuit is broken unless you it receive a signal to close it. For low voltage side it will connects to the NodeMCU ESP32 which consists of pins VCC, GND, INT1, INT2 and JD-VCC. IN1 and IN2 control pins for the bottom and top relays respectively. Meanwhile, JD-VCC is use to powers the relay's electromagnet. To control a grass cutter motor using NodeMCU ESP32 it need to connect the relay module. Connect the high-voltage side to DC motor and the low voltage side to

NodeMCU ESP32. Then Write code on NodeMCU ESP32 to control the relay. Lastly, Blynk application will trigger the relay to send a signal HIGH or LOW to the relay control pin IN1 or IN2 to activate or deactivate the relay.

3.4.6 3.7V 18650 LITHIUM-ION Battery

Figure 3.7: 12V Rechargeable Battery

The 3.7V lithium-ion rechargeable battery is a versatile and widely used power source due to its compact design, efficiency, and ability to be recharged. With a nominal voltage of 3.7V and a maximum voltage of 4.2V when fully charged, these batteries can reliably power various devices. Their capacities typically range from 1200mAh to 3500mAh, making them suitable for applications that require long-lasting performance.

For the 9V DC motors, two 3.7V batteries with a capacity of 1200mAh is connected in series for each motor pack. This configuration will provide a nominal voltage of 7.4V (8.4V when fully charged), which is slightly lower than 9V but will still allow the motors to operate effectively. The overall capacity of this pack remains at 1200mAh, determining the runtime based on the motors' power consumption.

For the 12V DC motor, three 3.7V batteries with a capacity of 2200mAh can be connected in series, delivering a nominal voltage of 11.1V (12.6V when fully charged). This voltage aligns well with the motor's requirements, and the higher capacity of 2200mAh ensures a longer runtime and better support for higher current demands compared to the 9V motor packs.

3.4.7 Blade

Figure 3.8: Blade for grass cutter

The figure 3.9 shows a retractable knife blade designed for use as a grass cutting tool. Three blades will be attached to a DC motor for this project. The design enables easy replacement of blades when needed. This blade is very sharp, ensuring a seamless grass cutting process. The blade's movement can be stopped using a reset button in case of an emergency.

3.4.8 Multi-Cell Type-C Step-Up Boost LiPo Polymer Li-Ion Charger 18650 Lithium

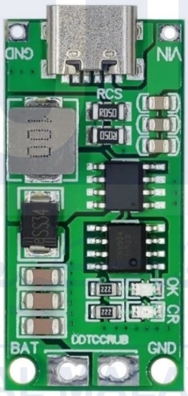

Figure 3.9: Multi-Cell Type-C Step-Up Boost LiPo Polymer Li-Ion Charger 18650 Lithium

The Lithium Battery Charging Module TP4056 18650 is designed for charging up to 18650 lithium-ion batteries. The module features a Type-C USB female socket as the input terminal, allowing for direct charging using a solar panel. It also includes solder joints for input voltage wiring, making it convenient for various projects. The module provides two-in-one charging and discharging protection. A red light indicates the charging process, while a green light signals that the batteries are fully charged. When connecting the battery for the first time, the protection circuit activates by charging it with a 5V voltage. If the battery is short-circuited and then reconnected, it needs to be charged again to activate the protection circuit.

Table 3.3: Specification of Module TP4056 18650

No	Specifications	Detail
1	Input Voltage	5.5V - 12.6V
2	Charge Voltage	6V
3	Maximum Charge Current	1A - 3A
4	Adjustable Charge Current	Yes
5	Charge Status Indication	Two LEDs (Red: Charging, Green: Done)
6	Protection Features	Overcharge, Over-discharge, Short Circuit, Overcurrent Protection
7	Operating Temperature	-40°C to +85°C
8	Charge Method	Linear Charging
9	Connector Type	Type C USB (input)
10	Dimensions	25mm x 19mm x 10mm

3.5 Software

3.5.1 Arduino IDE

Figure 3.10: Arduino IDE Logo

In this project, the Arduino Software (IDE) will be used to upload the code to a NodeMCU ESP32. With the help of this software, Arduino boards may be programmed and uploaded with code. You may write programmes in the text editor using the IDE, to start. These programmes are stored in files ending in.ino. The Arduino programming language allows users to construct bespoke functionality and control motors, sensors, and other components. You can upload the written code to your Arduino board. The software may be loaded straight onto the hardware thanks to the IDE's USB communication with the board. Additionally, the IDE offers code debugging tools. It has the ability to diagnose problems, display error messages, and monitor output on the serial monitor. Lastly, the Arduino IDE can be used offline, making it suitable for users with poor or no internet connection

3.5.2 Blynk Application

Figure 3.11: Blynk Application Logo

Blynk is a flexible IoT software platform that lets customers manage thousands of users and deployed goods, create mobile applications for remote management and monitoring, and connect devices to the cloud. Blynk will be utilised in this project to remotely monitor and operate the linked project. Through the Blynk app, it may interact with the project and visualize data. For the purpose of controlling relays, motors, and other electrical appliances, users may also design unique interfaces using widgets like as buttons, sliders, graphs, and gauges.

3.6 Flowchart

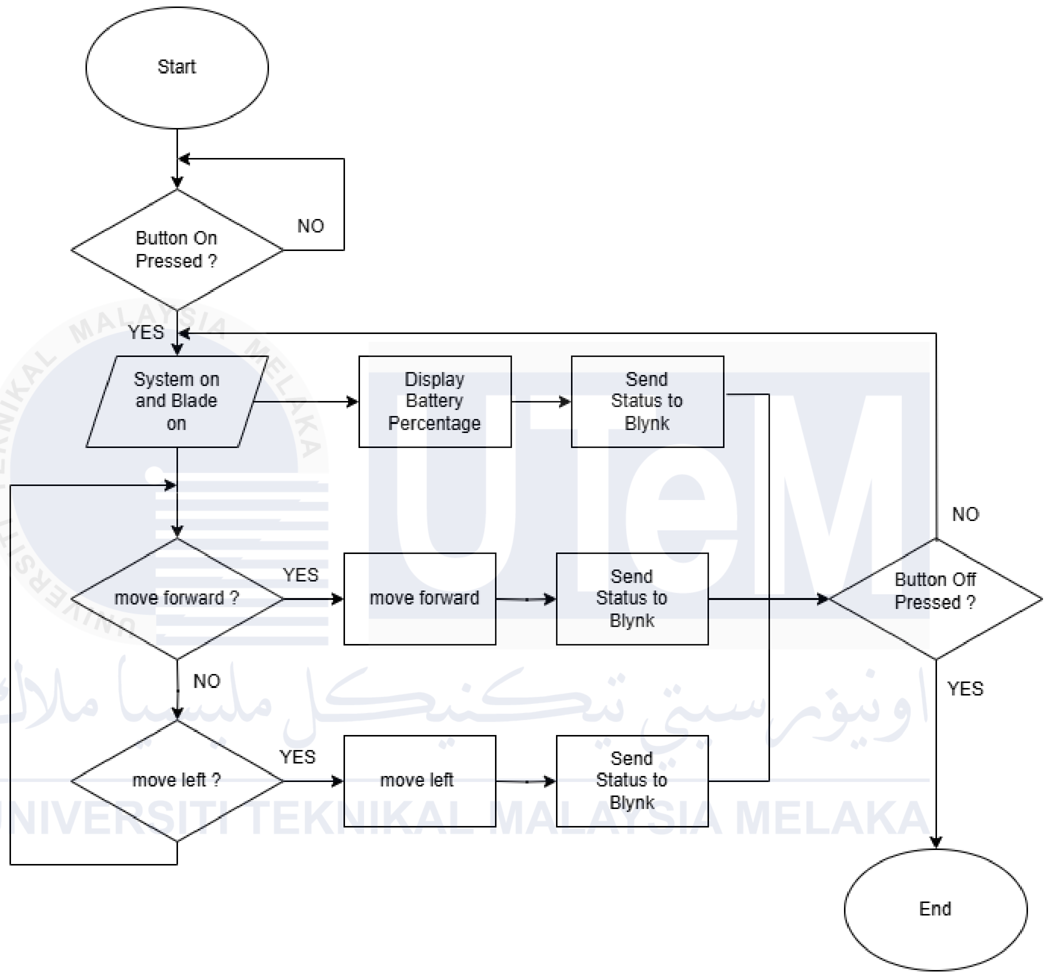

Figure 3.12: Flowchart

The flowchart in 3.12 outlines the operational logic of a system designed to control a device capable of moving in two directions: forward and left. The process begins with the initialization of the system. Initially, it checks if the power button is pressed. If the button is not pressed, the system remains in a waiting state until the button is pressed. Once the power button is pressed, the system and blade are turned on, indicating that the device is ready for operation.

Subsequently, the system enters a loop where it continuously checks for movement commands. It sequentially checks if the device should move forward or left. If a movement command is detected, the system performs the corresponding action (moving forward and left) and then sends the status update to Blynk, an application or service for monitoring IoT devices.

If no movement command is detected for any direction, the system checks if the reset button is pressed. If the reset button is pressed, the process ends, indicating that the system operation is terminated. If the reset button is not pressed, the system loops back to the initial step of checking the power button, thus repeating the cycle.

Overall, the flowchart presents a systematic approach to controlling the device's movements while continuously monitoring and updating its status and allowing for a reset command to terminate the operation.

3.7 Expected Result

The project's goal is to create a grass cutter that uses less conventional electricity by running mostly on solar power. Through decreased power use and a smaller carbon impact, this invention will support sustainability. It will increase the grass cutter's utility in far-off places by allowing it to function in regions with restricted access to the electrical grid.

The development of a robotic grass cutter that can be operated and observed via a specific mobile application would significantly improve user comfort. Remote control of the grass cutter's start, stop, and operation will enhance customer satisfaction overall. Timely maintenance and effective operation will be guaranteed by real-time monitoring of the cutter's state, battery level, and operational data. This addition, which offers an interactive and responsive lawn management tool, will not only boost user involvement but also enhance satisfaction.

Lastly, the grass cutter will be made to function without releasing dangerous emissions, improving the quality of the air. Because it will run on solar energy instead of gasoline, there won't be any exhaust emissions as with gasoline-powered mowers. The simplicity of use of the design will also be a priority, especially for older or impaired customers. Features like automatic operation, basic controls, and safety procedures could be part of this. The anticipated outcome is a clever, user-friendly grass cutter that supports inclusive and environmental sustainability while being simple to use for everyone.

3.8 Integrating IoT and Solar Energy for Sustainable and Inclusive Grass Cutting Solutions

The ”IoT-Based Solar Grass Cutting Robot” is a project that aligns closely with several Sustainable Development Goals (SDGs) by integrating innovative technology with environmental and social responsibility. By using solar energy as its primary power source, the robot significantly reduces dependence on fossil fuels and traditional electricity, contributing to the global transition toward clean and renewable energy. This not only lowers its operational carbon footprint but also serves as a practical example of sustainable energy systems, promoting energy efficiency and environmental conservation in line with SDG 7.

The design of this project contributes to the creation of sustainable urban environments by eliminating harmful air and noise pollution. Unlike traditional gas-powered lawnmowers, this solar-powered robot promotes cleaner air quality and operates more quietly, making it ideal for sensitive areas such as schools, hospitals, and residential neighbourhoods. This approach supports the development of healthier and more liveable cities and communities, in line with Sustainable Development Goal 11. Additionally, the eco-friendly nature of the robot demonstrates a commitment to reducing the environmental impact of lawn care, providing a sustainable alternative to conventional practices.

Furthermore, The project promotes climate action by tackling the challenges posed by greenhouse gas emissions. By utilizing renewable solar energy and adopting a zero-emission operational model, the robot effectively reduces its environmental impact and contributes to efforts against climate change. This aligns with Sustainable Development Goal 13, demonstrating how technological innovation can support global objectives for environmental sustainability. The design adopts a forward-thinking approach by integrating renewable energy with advanced IoT technology, highlighting the importance of innovation in promoting sustainable development.

Lastly, the grass-cutting robot features inclusive and user-friendly attributes that enhance accessibility for everyone. With IoT-based remote control through a mobile app, the robot is particularly beneficial for individuals with physical disabilities and the elderly, providing them with an easy and convenient gardening solution. This inclusivity aligns with Sustainable Development Goal 10 by reducing inequalities and ensuring that the advantages of technological advancements are available to diverse populations. By addressing both environmental and social aspects, the project demonstrates a holistic approach to sustainable development, combining innovation with a commitment to equity and environmental stewardship.

3.9 Summary

To summarize, this project has many important phases and adheres to a defined process. Installing the required hardware and software is the first step. The block diagram for the project is explained in order to make the general layout and operation of the system clear. The project flowchart graphic, which shows the sequential process flow, comes next.

Finding every piece of software and hardware that will be utilised to construct and programme the circuit is the next step. Conducting a comprehensive testing procedure is necessary to verify the programming and circuit operation. This phase also include figuring out easy fixes for any problems that could come up throughout the project. Ultimately, a thorough report that details every step of the process from setup to problem solving is generated to guarantee that all steps and results are understood.

CHAPTER 4

RESULTS AND DISCUSSION

An overview of the result and discussion related to the development of an IoT Based Smart Solar Grass Cutting Robot using NodeMCU ESP32 and Blynk Application is given in the upcoming chapter.

4.1 Introduction

The analysis in this chapter, ”Results and Discussion,” will be predicated on the information gathered and the observations made by the IoT Based Smart Solar Grass Cutting Robot using NodeMCU ESP32 and Blynk Application. The project’s software and hardware are described in this chapter. The system’s prototype was utilised to show off its capabilities. Different problems that arose during the process were also spoken about.

4.2 Schematic Diagram

Figure 4.1 shows the schematic diagram for IoT Based Smart Solar Grass Cutting Robot project.

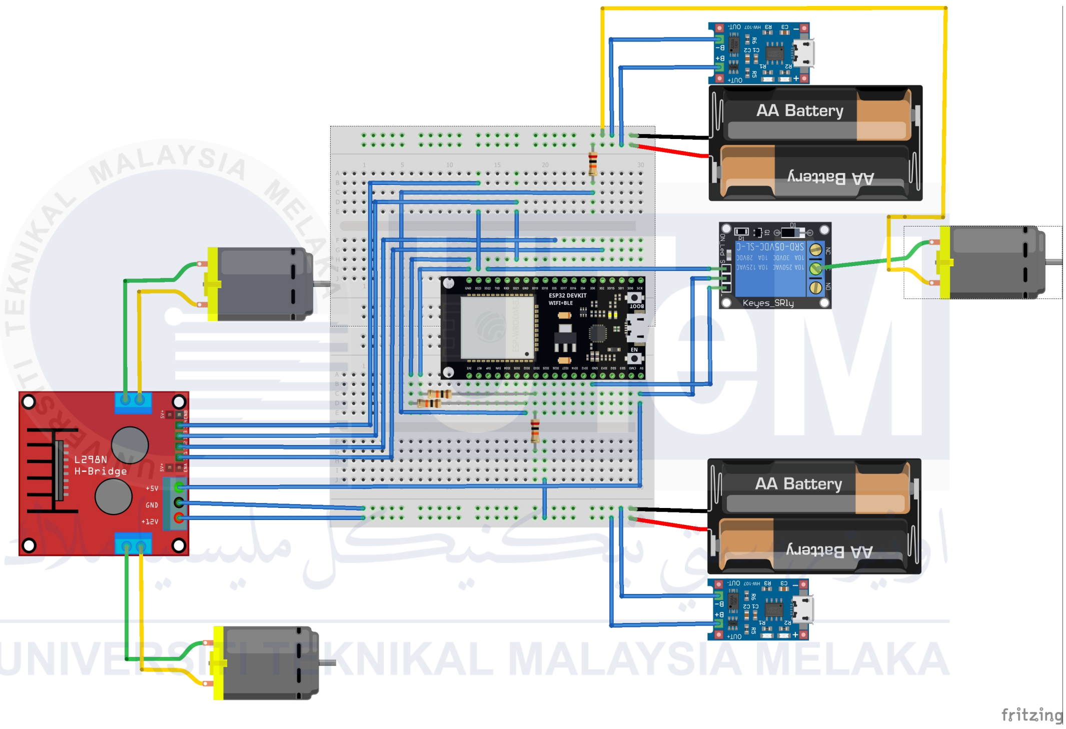

Figure 4.1: Schematic Diagram for IoT Based Solar Grass Cutting Robot Project

The figure 4.1 shows how an IoT based solar grass cutting robot that use Blynk application and NodeMCU ESP32 is designed. The NodeMCU ESP32 microcontroller, three DC motors, an H-Bridge motor driver, a relay module, two battery pack, and a voltage regulator module are among the essential parts. The NodeMCU ESP32 serves as the grass cutter's central controller, coordinating and supervising the functions of the motor driver, relay module. The battery is charge by solar panel. Then, entire circuit is powered by the battery pack and the voltage regulator makes sure that the ESP32 and other parts are receiving the right amount of power.

The grass cutter can move left and forward thanks to its 2 DC motors that are connected to the motor driver and one caster wheel. A DC motor for the cutting blades is operated by the relay module under the direction of the ESP32. Real-time data such as battery level and operating condition are displayed on the blynk application. The grass cutter may be controlled and monitored remotely thanks to communication between the NodeMCU ESP32 and the Blynk application. The ESP32 processes commands from the Blynk app to run the cutting motor through the relay module and regulate the movement of the grass cutter via the motor driver. This configuration guarantees an effective and user-friendly grass care instrument that is fueled sustainably by solar energy.

4.3 Hardware Implementation

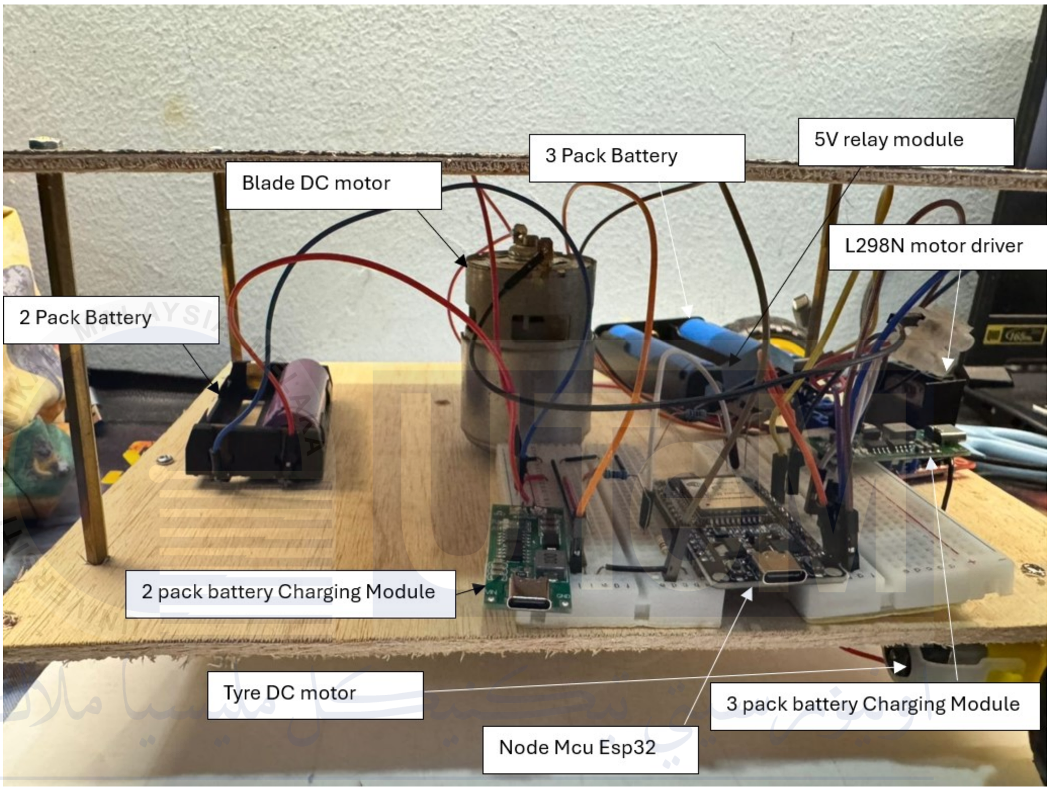

Figure 4.2: Circuit Setup for Hardware Implementation

A number of essential component make up the automated robotic application system is being shown in figure 4.2. The grass-cutting blade is powered by a Blade DC Motor, which is backed by a separate 2-pack battery. To ensure effective operation, additional components are powered by a separate 3-pack battery. By acting as a switch, the 5V Relay Module enables low-power signals from the NodeMCU ESP32 microcontroller to regulate high-power components, including the blade motor. The robot can move like a tank thanks to the L298N Motor Driver, which controls the Tyre DC Motors' speed and direction.

To provide a steady power supply, charging modules are included with both the 2-pack and 3-pack batteries. As the main controller of the system, the NodeMCU ESP32 controls every part and facilitates communication with the Blynk app for remote control and monitoring. This setup guarantees that the robot functions independently while still being able to be monitored and controlled remotely.

4.4 Software Implementation

The software implementation is ready in the Arduino IDE and has to be uploaded to the NodeMCU ESP32. This section included a library that was implemented, the functionality of several programs, and a connection to Blynk.

```
// Include required libraries
#define BLYNK_TEMPLATE_ID "TMPL6WuH02wps"
#define BLYNK_TEMPLATE_NAME "PSMTRY"
#define BLYNK_AUTH_TOKEN "XsXrdW5-rzDNHthZieF4YEV2YfvOuMJn"
#include <BlynkSimpleEsp32.h>
```

Figure 4.3: Library on NodeMCU ESP32

The code starts by including the Blynk library in figure 4.3, which allows for remote control and monitoring of the ESP32 device through the Blynk app. The #define directives are used to establish the template ID, template name, and authentication token for a specific Blynk project. These identifiers ensure that the ESP32 can connect to and communicate with the correct Blynk project.

```
// Define Blynk Auth Token, WiFi credentials
char auth[] = "XsXrdW5-rzDNHthZieF4YEV2YfvOuMJn";
char ssid[] = "POCO";
char pass[] = "123456789";
```

Figure 4.4: Wi-Fi Credentials

Next, the Wi-Fi credentials in figure 4.4 are defined as string variables with the Blynk login token. These parameters enable the ESP32 to connect to the given WiFi network and authenticate with the Blynk server, allowing for real-time communication between the hardware and the software.


```
// Define pins for motor control and battery monitoring
#define LEFT_MOTOR_PIN1  2
#define LEFT_MOTOR_PIN2  5
#define RIGHT_MOTOR_PIN1 21
#define RIGHT_MOTOR_PIN2 23
#define RELAY_PIN        22
#define BATTERY_PIN_2S   33
#define BATTERY_PIN_3S   32
```

Figure 4.5: Pins for motor control and battery monitoring

Then, GPIO pins are used to operate the motors, the blade motor relay, and read battery voltages. Specifically, two pins are designated to control the left motor and two for the right. The blade motor is controlled via a separate relay pin. In addition, the pins labelled BATTERYPIN2S and BATTERYPIN3S are used for analogue voltage readings from 2 and 3 battery packs.

```
// Function to send battery status
void sendBatteryStatus() {
  if (systemOn) {
    // Read and calculate for 2S battery
    batteryVoltage2S = readBatteryVoltage(BATTERY_PIN_2S, R1_2S, R2_2S);
    batteryPercentage2S = calculateBatteryPercentage(batteryVoltage2S, 6.0, 8.4);
    Blynk.virtualWrite(V5, batteryVoltage2S);        // Display 2S voltage on Blynk
    Blynk.virtualWrite(V6, batteryPercentage2S);     // Display 2S percentage on Blynk
    // Debugging 2S battery
    Serial.print("2S Battery Voltage: ");
    Serial.print(batteryVoltage2S);
    Serial.print(" V, Percentage: ");
    Serial.print(batteryPercentage2S);
    Serial.println(" %");
    // Read and calculate for 3S battery
    int adcValue3S = analogRead(BATTERY_PIN_3S);
    Serial.print("Raw ADC Value (3S): ");
    Serial.println(adcValue3S);
    if (adcValue3S > 0) {
      batteryVoltage3S = readBatteryVoltage(BATTERY_PIN_3S, R1_3S, R2_3S);
      batteryPercentage3S = calculateBatteryPercentage(batteryVoltage3S, 9.0, 12.6);
      Blynk.virtualWrite(V7, batteryVoltage3S);        // Display 3S voltage on Blynk
      Blynk.virtualWrite(V8, batteryPercentage3S);     // Display 3S percentage on Blynk
      // Debugging 3S battery
      Serial.print("3S Battery Voltage: ");
      Serial.print(batteryVoltage3S);
      Serial.print(" V, Percentage: ");
      Serial.print(batteryPercentage3S);
      Serial.println(" %");
    } else {
      Serial.println("3S battery ADC value is 0. Check connections and pin configuration.");
    }
  }
}
```

Figure 4.6: Setup for Battery Status

Furthermore, the figure 4.6 show the setup for battery status. The sendBatteryStatus function monitors and updates the status of two battery packs when the system is active systemOn. It first reads the analog voltage from the 2S battery pin using the readBatteryVoltage function and then calculates the battery percentage using calculateBatteryPercentage. These values are sent to the Blynk app for display on virtual pins V5 and V6, while debugging information is also output to the Serial Monitor.The function then performs the same process for the 3S battery, checking for valid ADC readings before calculating and sending the voltage and percentage to virtual pins V7 and V8. If the ADC value for the 3S battery is zero, it logs an error message, prompting a check of the connections and pin configuration. This ensures continuous monitoring and remote display of battery health.

```
// Movement functions using L298N motor driver
void moveForward() {
  digitalWrite(LEFT_MOTOR_PIN1, HIGH);
  digitalWrite(LEFT_MOTOR_PIN2, LOW);
  digitalWrite(RIGHT_MOTOR_PIN1, HIGH);
  digitalWrite(RIGHT_MOTOR_PIN2, LOW);
}
void moveBackward() {
  digitalWrite(LEFT_MOTOR_PIN1, LOW);
  digitalWrite(LEFT_MOTOR_PIN2, HIGH);
  digitalWrite(RIGHT_MOTOR_PIN1, LOW);
  digitalWrite(RIGHT_MOTOR_PIN2, HIGH);
}
void turnLeft() {
  digitalWrite(LEFT_MOTOR_PIN1, LOW);
  digitalWrite(LEFT_MOTOR_PIN2, HIGH);
  digitalWrite(RIGHT_MOTOR_PIN1, HIGH);
  digitalWrite(RIGHT_MOTOR_PIN2, LOW);
}
void turnRight() {
  digitalWrite(LEFT_MOTOR_PIN1, HIGH);
  digitalWrite(LEFT_MOTOR_PIN2, LOW);
  digitalWrite(RIGHT_MOTOR_PIN1, LOW);
  digitalWrite(RIGHT_MOTOR_PIN2, HIGH);
}
void stopMovement() {
  digitalWrite(LEFT_MOTOR_PIN1, LOW);
  digitalWrite(LEFT_MOTOR_PIN2, LOW);
  digitalWrite(RIGHT_MOTOR_PIN1, LOW);
  digitalWrite(RIGHT_MOTOR_PIN2, LOW);
}
// Function to control the blade motor via relay
void controlBladeMotor(bool state) {
  digitalWrite(RELAY_PIN, state ? HIGH : LOW);
}
```

Figure 4.7: Setup for Project Movement and Blade Status

This figure 4.7 outlines functions for controlling the movement of a motorized system utilizing a L298N motor driver and a relay-controlled blade motor. The functions moveForward, moveBackward, turnLeft, and turnRight employ digitalWrite commands to set the corresponding pins to HIGH or LOW, which determines the direction of current flow through the motors and facilitates the desired motion. The stopMovement function sets all motor control pins to LOW, effectively stopping any movement. Additionally, the controlBladeMotor function manages the blade motor by toggling the state of the relay pin based on the input parameter, allowing the blade motor to be turned on or off as necessary. These functions provide comprehensive control over both the movement and auxiliary motor operations.

```
void setup() {
  // Start serial communication
  Serial.begin(115200);
  // Initialize Blynk
  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);
  // Initialize motor pins as outputs
  pinMode(LEFT_MOTOR_PIN1, OUTPUT);
  pinMode(LEFT_MOTOR_PIN2, OUTPUT);
  pinMode(RIGHT_MOTOR_PIN1, OUTPUT);
  pinMode(RIGHT_MOTOR_PIN2, OUTPUT);
  pinMode(RELAY_PIN, OUTPUT);
  // Setup battery pins as inputs
  pinMode(BATTERY_PIN_2S, INPUT);
  pinMode(BATTERY_PIN_3S, INPUT);
  // Ensure the blade motor is off initially
  controlBladeMotor(false);
  // Set up timers for battery status
  timer.setInterval(1000L, sendBatteryStatus); // Update battery info every second
}
void loop() {
  // Run Blynk
  Blynk.run();
  // Run the timer
  timer.run();
}
```

Figure 4.8: System Initialization and Main Loop

Then, figure 4.8 explain the setup function configures the system's hardware and methods of communication. It establishes serial communication at a certain baud rate for debugging and monitoring. The ESP32 connects to the Blynk platform via the authentication token and Wi-Fi credentials provided by Blynk.begin. Motor control pins are marked as outputs, and battery monitoring pins as inputs. The controlBladeMotor function ensures that the blade motor is turned off at startup for safety reasons. In addition, a timer is set to call the sendBatteryStatus method every second, providing for periodic updates to the battery state. The loop function provides continuous operation by running the Blynk communication handler (Blynk.run) to maintain connectivity and process commands, and the timer (timer.run) handles scheduled chores like updating battery information.

Id	Name	Alias	Color	Pin	Data Type	Units	Is Ra	Actions
1	Motor Voltage	Motor Voltage		V5	Double	V	false	
2	stop	stop		V4	Integer		false	
3	Left	Left		V2	Integer		false	
4	grass cutter voltage	grass cutter voltage		V7	Integer	V	false	
5	Forward	Forward		V1	Integer		false	

Figure 4.9: Grass-Cutting Robot: Blynk Datastream Configuration

Futhermore, Blynk datastream is shown in figure 4.9 configuration is designed for controlling a grass-cutting robot. Each row corresponds to a control or monitoring parameter linked to a virtual pin that communicates with the robot's hardware. The parameters include "Motor Voltage" (V5), which monitors the main motor's voltage represented as a double-precision value in volts, and "Grass Cutter Voltage" (V7), which tracks the blade's voltage as an integer value in volts. The ”Stop” (V4) and ”Forward” (V1) controls use integers to manage movement states, while ”Left” (V2) controls the robot’s left-turn action.

4.5 Data Analysis

4.5.1 Battery Charging and Discharging Time

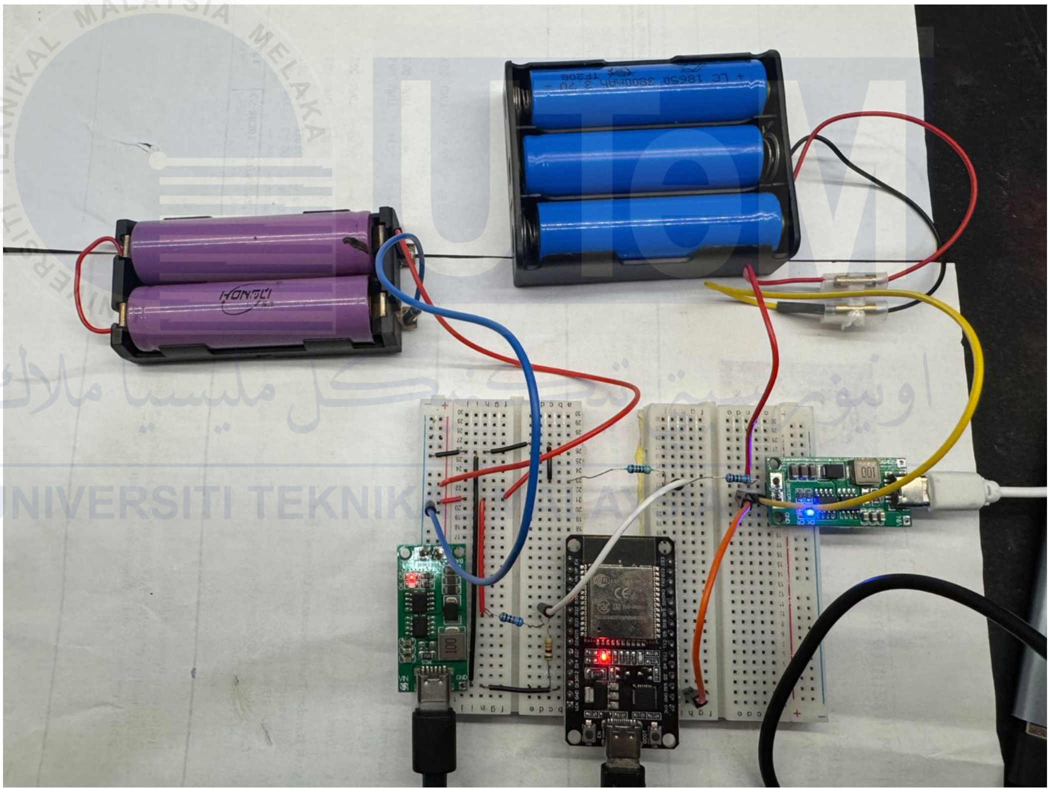

Figure 4.10: 2 pack and 3 pack battery charging

The figure 4.10 a solar-powered system designed to monitor and manage several components. It consists of two battery packs that power two DC motors and a three-battery pack that drives a grass cutter DC motor. The NodeMCU ESP32 functions as the central controller within the system. All components, including the batteries and the ESP32, are charged using a solar panel, which provides a sustainable and renewable energy source. The ESP32 monitors the battery voltages and communicates this data in real-time to the Blynk application, ensuring efficient oversight of the system's performance and energy management.

4.5.1.1 DC Motor Analysis

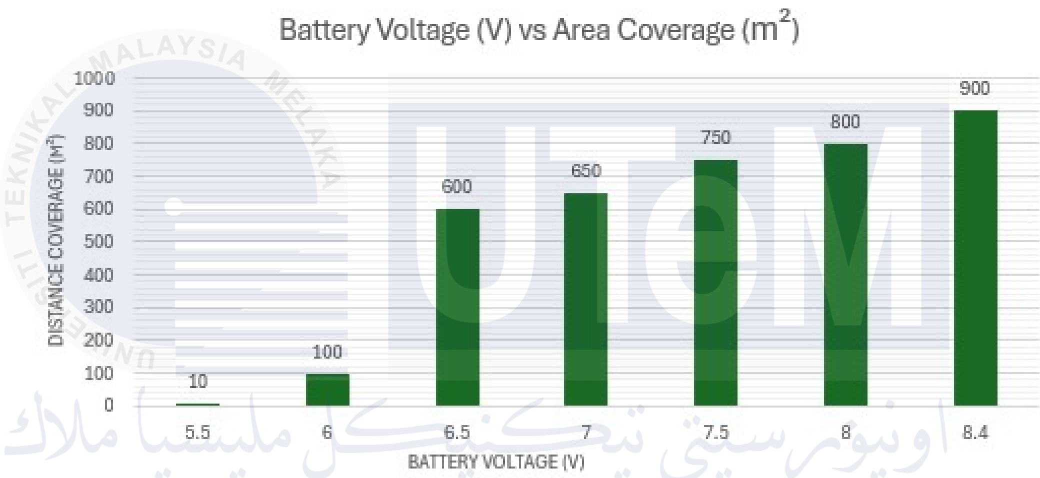

Figure 4.11: Relationship Between Dc motor Voltage and Area Coverage

The graph 4.11 illustrates the direct relationship between DC motor voltage and area coverage capabilities. The data shows that as the DC motor voltage increases from 5.5 volts to 8.4 volts, the distance that can be covered, measured in meters, also increases. At the lowest voltage point of 5.5 volts, the distance coverage is negligible, barely registering on the scale. When the voltage rises to 6 volts, the system can cover approximately 100 m². A significant improvement occurs at 6.5 volts, where the coverage extends to around 600 m². The trend continues steadily upward, with incremental increases in distance coverage as the voltage rises through 7 volts, 7.5 volts, and 8 volts. Finally, at the maximum tested voltage of 8.4 volts, the system achieves its peak performance, capable of covering nearly 900 m². This pattern strongly suggests that the system's range is heavily dependent on battery voltage, with higher voltage levels enabling substantially greater distance coverage.

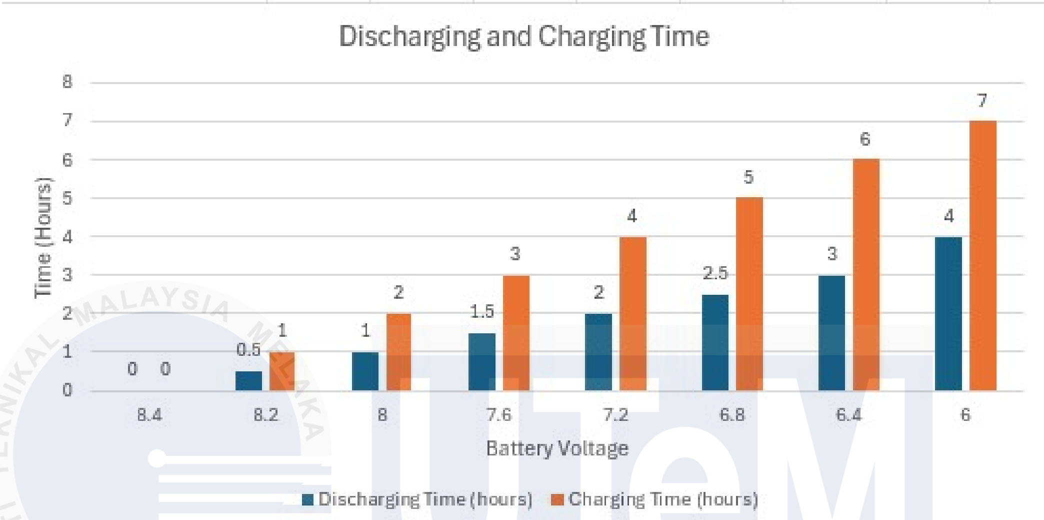

Figure 4.12: Relationship Between DC motor voltage's charging and discharging

Then, relationship between a DC motor voltage's charging and discharging times at various voltage levels is shown in the graph 4.12. As the voltage drops, there is a pattern of times increasing. Both charging and discharging periods are insignificant at higher voltage levels (8.4V), suggesting optimal performance or a completely charged state. However, both timing dramatically increase as the voltage drops to 6V, with the charging time (7 hours) continuously surpassing the discharging time (4 hours). According to this, the system loses efficiency at lower voltages and needs more time and energy to recharge than it does to discharge. The information also draws attention to possible inefficiencies and performance constraints at lower voltage levels, highlighting how crucial it is to maintain the ideal voltage for effective operation.

4.5.1.2 Grass Blade Analysis

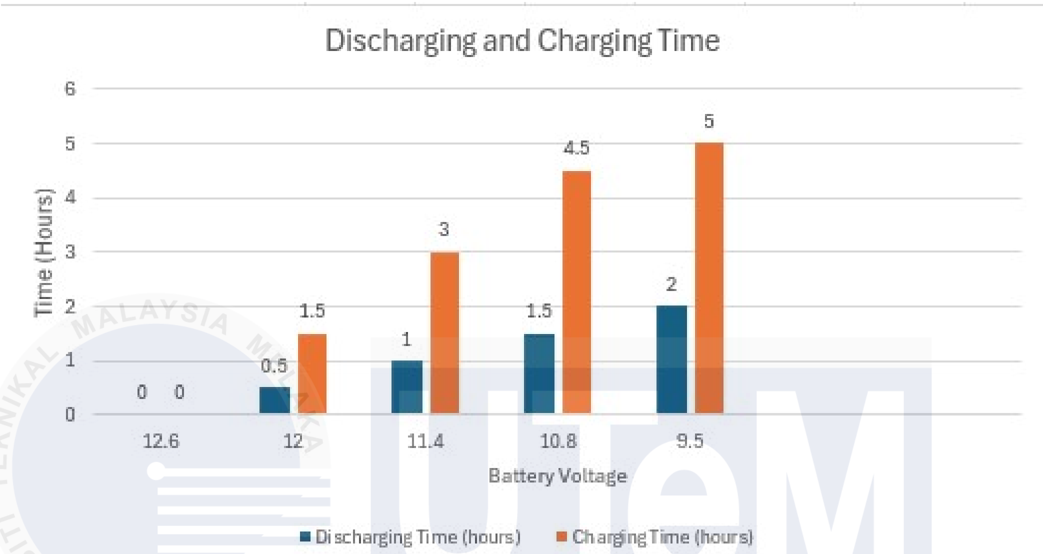

Figure 4.13: Relationship Between Grass Blade Voltage's Charging and Discharging

The graph 4.13 shown charging and discharging times of the grass blade voltage at various levels. At 12.6V, the grass blade system shows no discharging time, indicating that it is fully charged and ready for use, with a minimal charging time of just 0.5 hours. As the voltage decreases to 12V, the discharging time increases to 1.5 hours, indicating that the grass blade voltage is in use, while the charging time rises to 1 hour.

At 11.4V, the discharging time remains steady at 1.5 hours; however, the charging time significantly increases to 3 hours, suggesting a decrease in charging efficiency. At 10.8V, the discharging time rises slightly to 2 hours, while the charging time extends further to 4.5 hours, reflecting reduced efficiency as the voltage drops. At the lowest voltage of 9.5V, the discharging time stabilizes at 2 hours, but the charging time reaches its maximum of 5 hours, highlighting a substantial inefficiency in the recharging process.

Lastly, charging times considerably increase while discharging times stay mostly constant when the grass blade voltage drops. At lower voltages, where the charging time far outweighs the discharging time, the difference is most obvious and suggests decreased system efficiency. These findings highlight how important it is to keep the grass blade system operating within the ideal voltage range in order to balance charging and discharging efficiency. Lower voltage operation may result in longer charging periods and possibly worse performance, showing the importance of avoiding dangerous discharges for increased system longevity and efficiency.

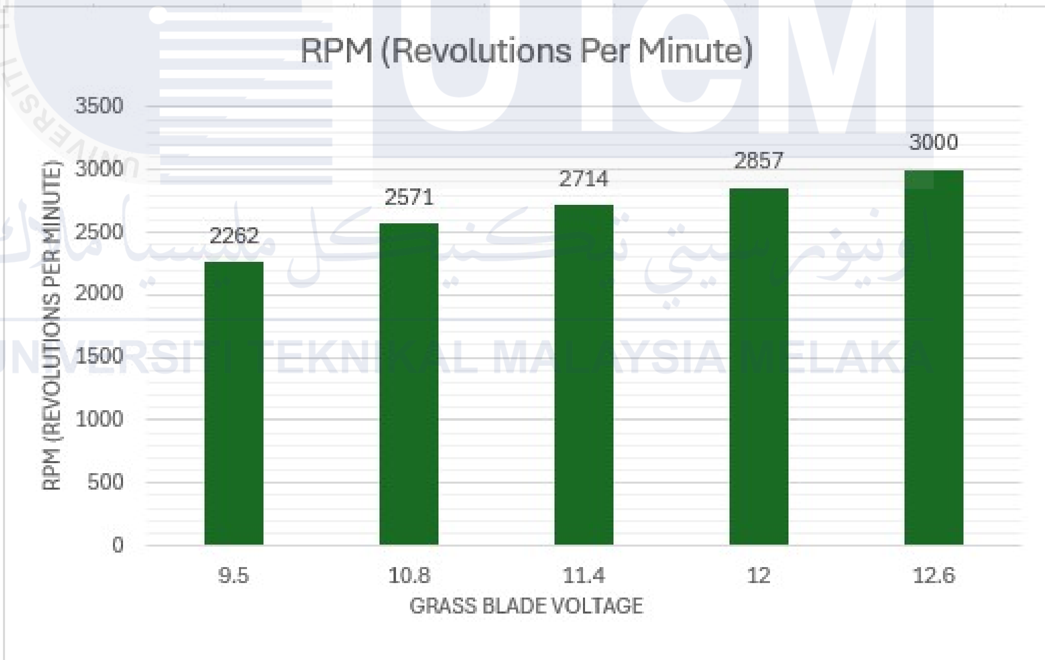

Figure 4.14: Relationship Between Grass Glade Voltage and RPM

The relationship between grass blade voltage and revolutions per minute (RPM) can be seen in the graph 4.14, which indicates that blade performance improves with increasing voltage. The RPM reaches its minimum of 2262 at the lowest voltage of 9.5V, demonstrating decreased blade speed and efficiency as a result of a constrained power supply. The RPM climbs to 2571 as the voltage rises to 10.8V, indicating improved performance with higher voltage. The RPM further rises to 2714 at 11.4V, demonstrating a consistent increase in rotational speed. The RPM reaches 2857 at 12V, indicating almost ideal performance as the system gets closer to its maximum capacity. Ultimately, the RPM peaks at 3000 at the maximum voltage of 12.6V, indicating optimal blade performance and efficiency at full power.

According to the research, there is a definite positive relationship between voltage and RPM. Greater voltages lead to faster blades and better system performance. At higher voltage levels (between 12V and 12.6V), where the RPM is maximum, optimal operation takes place, guaranteeing dependable and effective cutting capability. On the other hand, the system performs less well at lower voltages (9.5V to 10.8V), with a much lower RPM, which may affect performance. These findings emphasise how crucial it is to keep the grass blade system operating within the ideal voltage range in order to prevent inefficiencies brought on by an inadequate power source and to ensure reliable and efficient operation.

4.5.2 Blynk Application Interface

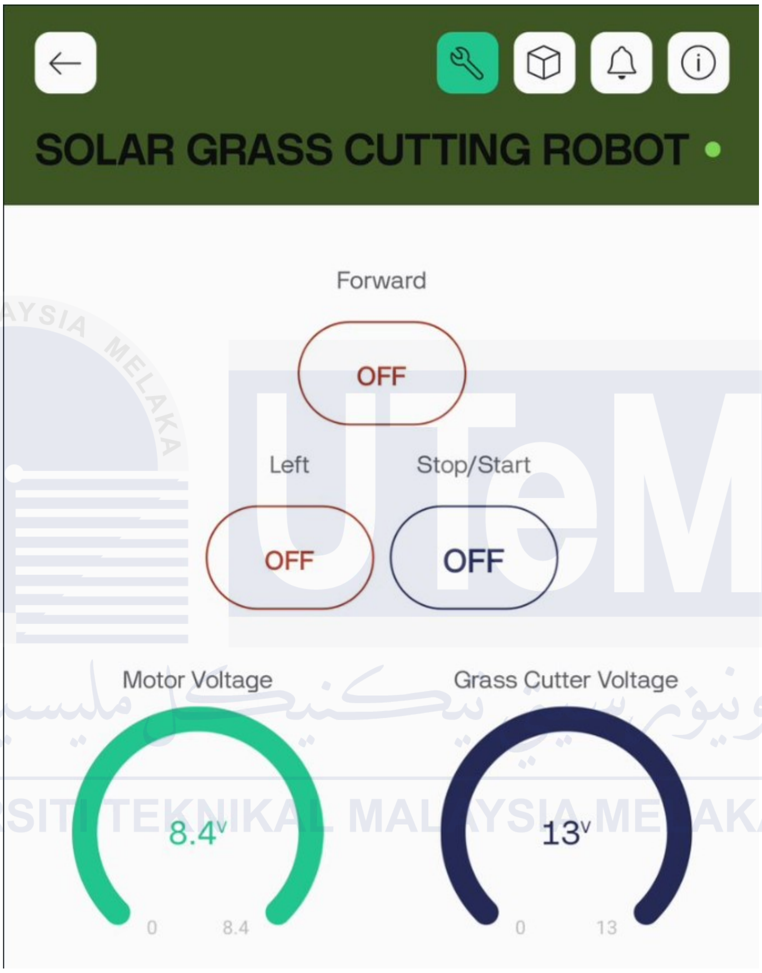

Figure 4.15: Blynk Application Interface Monitoring and Controlling Solar Grass Cutter Robot

The picture 4.15 shows the user interface of a Blynk software, which is used to operate and monitoring on a "Solar Grass Cutting Robot." The title and online status indication (shown by a green dot) on the dashboard verify that the robot is online and operational. The "Forward" button allows the robot to go forward, the "Left" button allows it to navigate left, and the ”Stop/Start” button stops or activates the robot. All of these controls are in the ”OFF” position at the moment.

Real-time voltage readings for two crucial components are displayed on the dashboard beneath the control buttons. The power supplied to the moving motors is indicated by the ”Motor Voltage” gauge, which reads 8.4V. The power available for the grass-cutting motor is indicated by the ”Grass Cutter Voltage” gauge, which reads 13V. Through this interface, users may control the robot from a distance while making sure that its solar-powered batteries retain the proper voltage levels for seamless and effective operation.

4.5.3 Movement of IoT Based Solar Grass Cutting Robot On Different Terrain

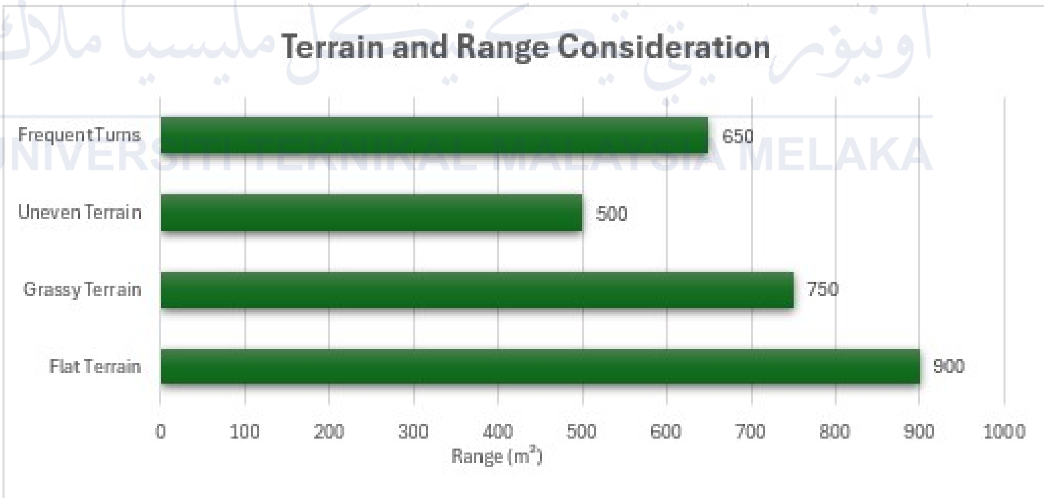

Figure 4.16: Relationship Between Robot Movement and Different Terrain

The graph 4.16 examines how various terrain types impact a system’s operational range of a solar-powered grass cutter. The maximum range in meters for each type of terrain is shown by the horizontal bars. The robot operates at its best on level ground, reaching a range of 900 meters. Smooth functioning and effective energy use are made possible by the lack of barriers. However, the range drops to 750 meters on grassy terrain because to the increased energy consumption caused by the extra effort needed to cut through the grass.

The range is further reduced to 650 meters on terrain with lots of twists since navigation and continuous directional changes use more energy. These situations show how the robot's operational range is directly impacted by terrains that present movement difficulties and inherent resistance. The biggest obstacle is uneven terrain, which restricts the robot's range to 500 meters.

This decrease is probably the result of the robot using more energy to avoid impediments, stay balanced, and function well on uneven surfaces.The graph emphasizes the importance of considering terrain types when deploying such a system, as they significantly influence the robot's efficiency, coverage area, and energy consumption.

4.5.4 Grass Blade Operation Analysis

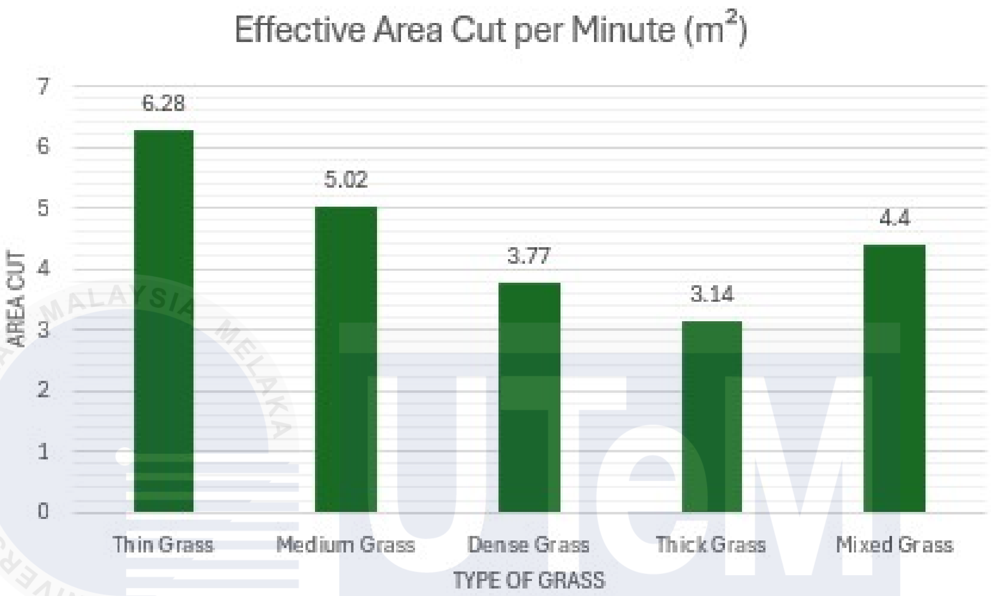

Figure 4.17: Effective Grass Cut Per Minute

The data 4.17 demonstrate the robot's versatility and effectiveness across several grass varieties, demonstrating its capacity to cut grass efficiently in a variety of situations. The robot reaches maximum efficiency for Thin Grass, cutting 6.28 m² per minute. Because of the grass's low density, the blade encounters less resistance, enabling the motor to run at maximum efficiency while using the least amount of energy. This makes it perfect for well-kept lawns.

The higher resistance in Medium Grass causes the effective cutting area to drop to 5.02 m² per minute, which has a moderate influence on the blade's efficiency. In relatively thick fields or home gardens, this situation is typical.The effective cutting rate further decreases to 3.77 m^2 per minute while cutting dense grass, illustrating how the motor's performance is greatly impacted by increased grass density. The robot performs at its worst over thick grass, managing only 3.14 m^2 per minute due to the blade's strong resistance. These difficult circumstances could strain the motor to its breaking point, emphasising the necessity of strong torque and efficient safety systems to avoid damage or overheating.

Last but not least, the robot dynamically adapts to changes in density within the same area to reach a balanced performance of 4.4 m^2 per minute when working with Mixed Grass. These differences in cutting efficiency show how the robot's performance is affected by the density of the grass. The information is useful for planning operations, predicting cutting times, and optimising energy use for various terrains. It also demonstrates the robot's adaptability, guaranteeing efficient performance on a variety of grass varieties.

4.5.5 Time Comparison between IoT Solar Grass Cutter and Standard Grass Cutter

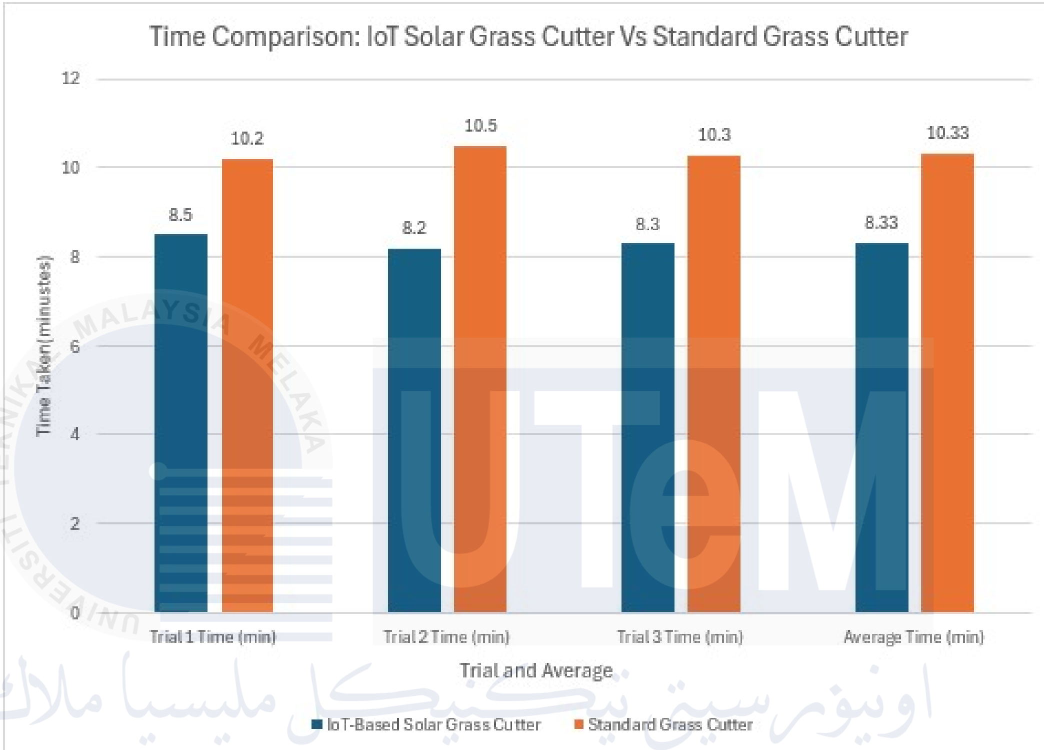

Figure 4.18: Time Comparison IoT Solar Grass Cutter and Standard Grass Cutter

This bar chart in 4.18 compares the time taken between an IoT based solar grass cutter and a standard grass cutter across three trials, along with their average times. In each trial, the IoT based grass cutter consistently outperformed the standard cutter, completing the task more quickly. For instance, in Trial 1, the IoT based grass cutter took 8.5 minutes, while the standard cutter required 10.2 minutes. This trend continued in subsequent trials, with the IoT gras cutter demonstrating superior efficiency, resulting in a lower average time of 8.33 minutes compared to 10.33 minutes for the standard cutter.

The graph clearly illustrates the efficiency advantage of the IoT based grass cutter, which maintained steady performance across all trials. This consistent speed highlights its advanced automation and optimized operation, showcasing its ability to reduce the time needed for lawn care. In contrast, the standard cutter took more time in each trial, likely due to manual operation and less precise control. Overall, the visual representation emphasizes the IoT based grass cutter's potential to enhance productivity and decrease effort compared to traditional grass cutting methods.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this project, Development of IoT Based Smart Solar Grass Cutting Robot using NodeMCU ESP32 and Blynk Application has been developed. The project has been divided into three main objectives as described in Section 1.3. The accomplishment for each objective is described and concluded in this chapter.

The first objective is achieved by when the creation of a solar-powered lawn cutter reduces dependency on conventional electricity and offers a practical and affordable alternative. This invention improve usability in isolated areas with restricted access to the electrical grid in addition to reducing the carbon footprint and operating expenses. This grass cutter will greatly advance environmental sustainability and increase the availability of lawn care technologies by utilising solar energy.

The second objective is achieved by when the creation of a robotic grass cutter that paired with Blynk application going to greatly improve user convenience and engagement. The user experience will be enhanced by having remote start, stop, and control over the grass cutter in addition to real-time status, battery level, and operational metrics monitoring. Higher user satisfaction and a more efficient lawn care procedure will result from the timely and effective operation and maintenance provided by this interactive and responsive solution.

The third objective is achieved by when user with inclusiveness and environmental sustainability had be given top priority in the grass cutter's design. It will lessen dependency on petrol and improve air quality by running on solar power and removing dangerous pollutants. Its easy-to-use features, such safety safeguards, straightforward controls, and automatic operation, will enable elderly and disabled customers to utilise it. The ultimate product will be an intelligent, environmentally friendly lawn cutter that is simple to use for everyone, encouraging environmental sustainability and inclusion.

5.2 Future Works

There are many improvements that may be performed to guarantee that this project is relevant in the future. Future research should take these enhancements into account as they will help to improve the IoT-based smart solar grass-cutting robot's functionality, efficiency, and user experience.

Advanced Navigation and Automation:

- By using machine learning and artificial intelligence it allow the robot to learn from different grass conditions and adjust its cutting patterns for greater intelligence and efficiency.
- To guarantee safe and continuous operation, the robot's sensors and algorithms should be improved for improved obstacle recognition and avoidance.

Durability and weather resistance:

- Improve the physical design's resilience to different weather conditions and durability to ensure dependable functioning in a range of climates.
- Develop a self-cleaning system to keep debris and grass clippings from interfering with the robot's functionality..

Enhanced Safety Features:

- To guarantee user safety, include more safety measures such kid safety locks, emergency stop buttons, and better blade shielding.
- Provide a real-time alert system that notifies users instantly in the event of dangers or problems..

5.3 Potential Of Commercialization

The "IoT-Based Solar Grass Cutting Robot" has significant commercialization potential due to its unique combination of sustainable energy use, smart technology, and user-friendly design. As global demand for eco-friendly and energy-efficient products increases, this robot aligns perfectly with current market trends. Its reliance on solar energy eliminates the need for fuel or traditional electricity, greatly reducing operational costs. This feature appeals to both residential users and businesses, such as landscaping companies, that are looking for sustainable alternatives. Furthermore, the integration of IoT for remote monitoring and control enhances the product's attractiveness in the expanding smart home and automation market, creating opportunities for global commercialization.

The practical applications of this project go beyond individual use and provide value to various sectors within the community. It can be utilized in public spaces such as parks, schools, and hospitals, where it is important to maintain green areas without contributing to noise or air pollution. Its ability to operate autonomously and efficiently makes it an excellent resource for municipalities looking to reduce maintenance costs and environmental impact. Additionally, agricultural applications could benefit from this technology by enabling precise grass cutting in specific areas, further demonstrating its versatility. The robot's compatibility with renewable energy sources ensures its effectiveness in remote locations with limited access to the electricity grid, addressing the community's needs for sustainable and practical solutions.

The robot addresses community needs by promoting accessibility and inclusivity. It is especially beneficial for the elderly and individuals with physical disabilities, who often struggle with manual lawn maintenance. Its user-friendly design, along with an IoT-based mobile app for control, allows for effortless operation, ensuring independence and convenience for a wide range of users. Moreover, the robot operates without pollution, aligning with the community's increasing awareness of environmental health and sustainability. By addressing both functional and social needs, the project has the potential to make a meaningful impact on the quality of life while fostering a cleaner and more sustainable environment.

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APPENDICES

Appendix A: Full code of IoT Based Solar Grass Cutting Robot

```
// Include required libraries
#define BLYNK_TEMPLATE_ID "TMPL6WuHO2wps"
#define BLYNK_TEMPLATE_NAME "PSMTRY"
#define BLYNK_AUTH_TOKEN "XsXrdW5-rzDNHthZieF4YEV2YfvOuMJn"
#include <BlynkSimpleEsp32.h>

// Define Blynk Auth Token, WiFi credentials
char auth[] = "XsXrdW5-rzDNHthZieF4YEV2YfvOuMJn";
char ssid[] = "POCO";
char pass[] = "123456789"; // Replace with your WiFi Password

// Define pins for motor control and battery monitoring
#define LEFT_MOTOR_PIN1  2
#define LEFT_MOTOR_PIN2  5
#define RIGHT_MOTOR_PIN1 21
#define RIGHT_MOTOR_PIN2 23
#define RELAY_PIN        22
#define BATTERY_PIN_2S   33
#define BATTERY_PIN_3S   32

// Variables for battery monitoring
float batteryVoltage2S = 0;
float batteryVoltage3S = 0;
int batteryPercentage2S = 0;
int batteryPercentage3S = 0;
bool systemOn = true; // System state

// Resistor values for voltage dividers (updated)
```

```
const float R1_2S = 20000.0; // 20k ohms
const float R2_2S = 10000.0; // 10k ohms
const float R1_3S = 20000.0;
const float R2_3S = 4700.0; // Two 10k in parallel
const float maxADC = 4095.0;
const float referenceVoltage = 3.3;

// Timer for periodic actions
BlynkTimer timer;

// Button virtual pins
#define BUTTON_FORWARD    V0
#define BUTTON_BACKWARD   V1
#define BUTTON_LEFT       V2
#define BUTTON_RIGHT      V3
#define BUTTON_START_STOP V4

// Function to read battery voltage
float readBatteryVoltage(int pin, float R1, float R2) {
  int adcValue = analogRead(pin);
  float voltage = (adcValue / maxADC) * referenceVoltage;
  Serial.print("Raw ADC Value (Pin ");
  Serial.print(pin);
  Serial.print("): ");
  Serial.println(adcValue);
  return voltage * (R1 + R2) / R2;
}

// Function to calculate battery percentage
int calculateBatteryPercentage(float voltage, float minVoltage, float maxVoltage) {
  if (voltage >= maxVoltage) return 100;
  if (voltage <= minVoltage) return 0;
  return (int)((voltage - minVoltage) / (maxVoltage - minVoltage) * 100);
```

```
}

// Function to send battery status
void sendBatteryStatus() {
  if (systemOn) {
    // Read and calculate for 2S battery
    batteryVoltage2S = readBatteryVoltage(BATTERY_PIN_2S, R1_2S, R2_2S);
    batteryPercentage2S = calculateBatteryPercentage(batteryVoltage2S, 6.0, 8.4);
    Blynk.virtualWrite(V5, batteryVoltage2S);        // Display 2S voltage on Blynk
    Blynk.virtualWrite(V6, batteryPercentage2S);     // Display 2S percentage on Blynk

    // Debugging 2S battery
    Serial.print("2S Battery Voltage: ");
    Serial.print(batteryVoltage2S);
    Serial.print(" V, Percentage: ");
    Serial.print(batteryPercentage2S);
    Serial.println(" %");

    // Read and calculate for 3S battery
    int adcValue3S = analogRead(BATTERY_PIN_3S);
    Serial.print("Raw ADC Value (3S): ");
    Serial.println(adcValue3S);

    if (adcValue3S > 0) {
      batteryVoltage3S = readBatteryVoltage(BATTERY_PIN_3S, R1_3S, R2_3S);
      batteryPercentage3S = calculateBatteryPercentage(batteryVoltage3S, 9.0, 12.6);
      Blynk.virtualWrite(V7, batteryVoltage3S);        // Display 3S voltage on Blynk
      Blynk.virtualWrite(V8, batteryPercentage3S);     // Display 3S percentage on Blynk

      // Debugging 3S battery
      Serial.print("3S Battery Voltage: ");
      Serial.print(batteryVoltage3S);
      Serial.print(" V, Percentage: ");
```

```
      Serial.print(batteryPercentage3S);
      Serial.println(" %");
    } else {
      Serial.println("3S battery ADC value is 0. Check connections and pin configuration.");
    }
  }
}

// Movement functions using L298N motor driver
void moveForward() {
  digitalWrite(LEFT_MOTOR_PIN1, HIGH);
  digitalWrite(LEFT_MOTOR_PIN2, LOW);
  digitalWrite(RIGHT_MOTOR_PIN1, HIGH);
  digitalWrite(RIGHT_MOTOR_PIN2, LOW);
}

void moveBackward() {
  digitalWrite(LEFT_MOTOR_PIN1, LOW);
  digitalWrite(LEFT_MOTOR_PIN2, HIGH);
  digitalWrite(RIGHT_MOTOR_PIN1, LOW);
  digitalWrite(RIGHT_MOTOR_PIN2, HIGH);
}

void turnLeft() {
  digitalWrite(LEFT_MOTOR_PIN1, LOW);
  digitalWrite(LEFT_MOTOR_PIN2, HIGH);
  digitalWrite(RIGHT_MOTOR_PIN1, HIGH);
  digitalWrite(RIGHT_MOTOR_PIN2, LOW);
}

void turnRight() {
  digitalWrite(LEFT_MOTOR_PIN1, HIGH);
  digitalWrite(LEFT_MOTOR_PIN2, LOW);
```

```
  digitalWrite(RIGHT_MOTOR_PIN1, LOW);
  digitalWrite(RIGHT_MOTOR_PIN2, HIGH);
}

void stopMovement() {
  digitalWrite(LEFT_MOTOR_PIN1, LOW);
  digitalWrite(LEFT_MOTOR_PIN2, LOW);
  digitalWrite(RIGHT_MOTOR_PIN1, LOW);
  digitalWrite(RIGHT_MOTOR_PIN2, LOW);
}

// Function to control the blade motor via relay
void controlBladeMotor(bool state) {
  digitalWrite(RELAY_PIN, state ? HIGH : LOW);
}

// Blynk button functions
BLYNK_WRITE(BUTTON_FORWARD) {
  if (param.asInt()) {
    moveForward();
  } else {
    stopMovement();
  }
}

BLYNK_WRITE(BUTTON_BACKWARD) {
  if (param.asInt()) {
    moveBackward();
  } else {
    stopMovement();
  }
}

```

```
BLYNK_WRITE(BUTTON_LEFT) {
  if (param.asInt()) {
    turnLeft();
  } else {
    stopMovement();
  }
}

BLYNK_WRITE(BUTTON_RIGHT) {
  if (param.asInt()) {
    turnRight();
  } else {
    stopMovement();
  }
}

BLYNK_WRITE(BUTTON_START_STOP) {
  if (param.asInt()) {
    controlBladeMotor(true);
  } else {
    controlBladeMotor(false);
    stopMovement();
  }
}

void setup() {
  // Start serial communication
  Serial.begin(115200);

  // Initialize Blynk
  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);

  // Initialize motor pins as outputs
```

```
  pinMode(LEFT_MOTOR_PIN1, OUTPUT);
  pinMode(LEFT_MOTOR_PIN2, OUTPUT);
  pinMode(RIGHT_MOTOR_PIN1, OUTPUT);
  pinMode(RIGHT_MOTOR_PIN2, OUTPUT);
  pinMode(RELAY_PIN, OUTPUT);

  // Setup battery pins as inputs
  pinMode(BATTERY_PIN_2S, INPUT);
  pinMode(BATTERY_PIN_3S, INPUT);

  // Ensure the blade motor is off initially
  controlBladeMotor(false);

  // Set up timers for battery status
  timer.setInterval(1000L, sendBatteryStatus); // Update battery info every second
}

void loop() {
  // Run Blynk
  Blynk.run();

  // Run the timer
  timer.run();
}
```