Faculty of Engineering

IOT-BASED SOLAR PANELS AUTOMATED CLEANING SYSTEM USING ARDUINO MICROCONTROLLER

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IOT-BASED SOLAR PANELS AUTOMATED CLEANING SYSTEM USING ARDUINO MICROCONTROLLER

NURUL LIYANA BINTI YA'AKUP

A dissertation submitted in partial fulfilment
of the requirement for the degree of
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ABSTRACT

This project provides a description of the design and construction of an automated cleaning system for solar panels. Such a system has the potential to improve the effectiveness of solar panels and the amount of energy that they produce. The primary objective of this project is to create an automated solar panel cleaning system that is both low in cost and reliable, and it will be built on the Internet of Things (IoT). The accumulation of dust on solar panels is the source of the issue, which in turn hinders the panels' ability to work effectively and efficiently. The presence of dust decreases the quantity of sunlight that is able to reach the photovoltaic cells, which in turn results in a lower amount of power being generated. This problem is especially widespread in settings that are open and have a high potential for the collection of dust. As a result, an automatic cleaning system for solar panels is going to be developed as part of this project. The dust sensor served as a framework for the design of this cleaning system. A communication protocol is provided by the ESP32 Wi-Fi module, while the Arduino UNO board serves as the primary control unit. The proposed system is made up of three different parts: a sensor that detects and processes the amount of dust, a microcontroller that activates a windscreen wiper system, and a controller that manages the cleaning procedure. These systems are simple to control and may be monitored using an intuitive user interface designed for mobile devices such as smartphones. This project can make use of an Internet of Things (IoT)-based automatic cleaning system for solar panels. Using Internet connections, the monitoring of this automated cleaning system can be done through ThingSpeak. Installing mobile applications on mobile phones, such as the Blynk application, gives users the ability to monitor and control the cleaning system of solar panels. Data analysis is used in this study to investigate how the performance of solar panels is affected by the deposition of dust. The findings indicate that the automated cleaning system is responsible for an improvement in solar panel production of more than 10%, resulting in an increase in productivity of 15.04% from 46.97W to 75.10W. In conclusion, the goals of this study were effectively accomplished through the development of an Internet of Things-based automatic cleaning system for solar panels. In subsequent studies, it is crucial to address these constraints and investigate potential new lines of inquiry.

ABSTRAK

Projek ini memberikan penerangan tentang reka bentuk dan pembinaan sistem pembersihan automatik untuk panel solar. Sistem sedemikian berpotensi untuk meningkatkan keberkesanan panel solar dan jumlah tenaga yang dihasilkannya. Objektif utama projek ini adalah untuk mencipta sistem pembersihan panel solar automatik yang berkos rendah dan ia akan dibina di *Internet of Things (IoT).* Pengumpulan habuk pada panel solar adalah punca isu, yang seterusnya menghalang keupayaan panel untuk berfungsi dengan berkesan dan cekap. Kehadiran habuk mengurangkan kuantiti cahaya matahari yang mampu mencapai sel fotovoltaik, yang seterusnya mengakibatkan jumlah kuasa yang dihasilkan lebih rendah. Masalah ini meluas terutamanya dalam tetapan yang terbuka dan mempunyai potensi tinggi untuk pengumpulan habuk. Hasilnya, sistem pembersihan automatik untuk panel solar akan dibangunkan sebagai sebahagian daripada projek ini. Penderia habuk berfungsi sebagai rangka kerja untuk reka bentuk sistem pembersihan ini. Protokol komunikasi disediakan oleh modul *Wi-Fi ESP32*, manakala papan *Arduino UNO* berfungsi sebagai unit kawalan utama. Sistem yang dicadangkan terdiri daripada tiga bahagian berbeza: sensor yang mengesan dan memproses jumlah habuk, mikropengawal yang mengaktifkan sistem pengelap cermin depan dan pengawal yang menguruskan prosedur pembersihan. Sistem ini mudah dikawal dan dapat dipantau menggunakan pengguna intuitif yang direka untuk peranti mudah alih seperti telefon pintar. Projek ini boleh menggunakan sistem pembersihan automatik berasaskan *Internet of Things (IoT)* untuk panel solar. Menggunakan sambungan Internet, pemantauan sistem pembersihan automatik ini boleh dilakukan melalui *ThingSpeak*. Memasang aplikasi mudah alih pada telefon mudah alih, seperti aplikasi *Blynk*, memberikan pengguna keupayaan untuk memantau dan mengawal sistem pembersihan panel solar. Analisis data digunakan dalam kajian ini untuk menyiasat bagaimana prestasi panel solar dipengaruhi oleh pemendapan habuk. Penemuan menunjukkan bahawa sistem pembersihan automatik bertanggungjawab untuk peningkatan dalam pengeluaran panel solar lebih daripada 10%, menyebabkan peningkatan dalam produktiviti sebanyak 15.04% daripada 46.97W kepada 75.10W. Kesimpulannya, matlamat kajian ini telah dicapai dengan berkesan melalui pembangunan sistem pembersihan automatik berasaskan *IoT*.

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LIST OF ABBREVIATIONS

DC	-	Direct Current
PV	-	Photovoltaic
Arduino IDE	-	Arduino Integrated Development Environment
GSM	-	Global System for Mobile communication
Wi-Fi	-	Wireless Fidelity
PLC	-	Programmable Logic Controller
IR LEDs	-	Infrared Light Emitting Diode
HMI	-	Human-Machine Interface
LAN	-	Local Area Network
IoT	-	Internet of Things
SCM	-	Self-Cleaning Mechanism
CNN	-	Convoluted Neural Networks
LDR	-	Light Dependent Resistors
SCADA	-	Supervisory Control and Data Acquisition
ADC	-	Analog to Digital Converter
GPIO	-	General Purpose Input Output
EEPROM	-	Electrically Erasable Programmable Read-Only Memory
SRAM	-	Static Random Access Memory
PWM	-	Pulse Width Modulation

CHAPTER 1

INTRODUCTION

1.1 Background

Solar energy is the most environmentally sustainable, abundant, inexhaustible, and easily available form of energy on the earth. Solar energy has the potential to fulfil the world's present and future energy demands. The energy sector is likewise interested in supplying power in a green and sustainable manner. Despite the high cost of installation, solar systems are frequently employed to fulfil the rising power demand. Photovoltaic panels have a lifespan of around 30 years [1]. Widespread adoption of photovoltaic systems to meet the rising demand for power. Despite the astronomical expense of initial installation, solar panel installation is expanding daily. Photovoltaic modules are increasing in both independent and grid-connected configurations.

Photovoltaic (PV) solar panels are used to transform sunlight into DC electricity in a solar energy system. After the installation of solar panels, gasoline is no longer a cost. Solar energy is a sustainable energy source that emits no carbon dioxide; nonetheless, solar panels require periodic maintenance. The dust particles that are accumulating on the solar panel are almost entirely the result of urban and industrial goods. There are many different kinds of dust that may be found on solar panels, including SiO_2, Al_2O_3, Fe_2O_3, $CaMg(CO_3)_2$, $Ca(OH)_2$, CaO, and $CaCO_3$ [2]. When there is a buildup of dust on the surface of the solar panels, the efficiency of the solar power system suffers as a direct result. According to some estimations, the efficiency of a system can decreases by up to fifty percent, and more than fifteen percent of its power can be wasted [3]. Consequently, it is essential to maintain the surface of the solar panels in the cleanest possible condition.

Figure 1.1: Solar Panels with dust accumulation [4]

A research done by Adinoyi and Said in 2013 [5] on solar panels left uncleansed and exposed to sunshine for about six months in the eastern region of Saudi Arabia revealed that dust reduces the output power of solar panels by up to 50 percent. Solar panel performance is greatly reliant on the amount of sunlight hitting the solar cell. Due to dust collection or soiling, the solar cell's irradiance is drastically decreased, resulting in a decrease in performance.

Another study was conducted by Sulaiman and Mat in 2015 [6] on solar panels that were put on the roof of a building 200 kilometers north of Kuala Lumpur, in an area that was surrounded by rainforest and exposed to sunlight. From the hourly test through the three-month test, the histogram in Figure 1.2 shows that the total amount of electrical power produced continuously falls until it reaches its lowest point. The reduction in the average over the course of the three-month test is 0.85%, which is lower than the reduction of 1.57% over the course of the monthly test. In a similar vein, the average over the course of ninety days, or three months, would be 0.03%, which is lower than the average over the course of a single day, which is 0.57%. The findings suggest that the pace of decline in the generation of electrical power will slow down over the course of time.

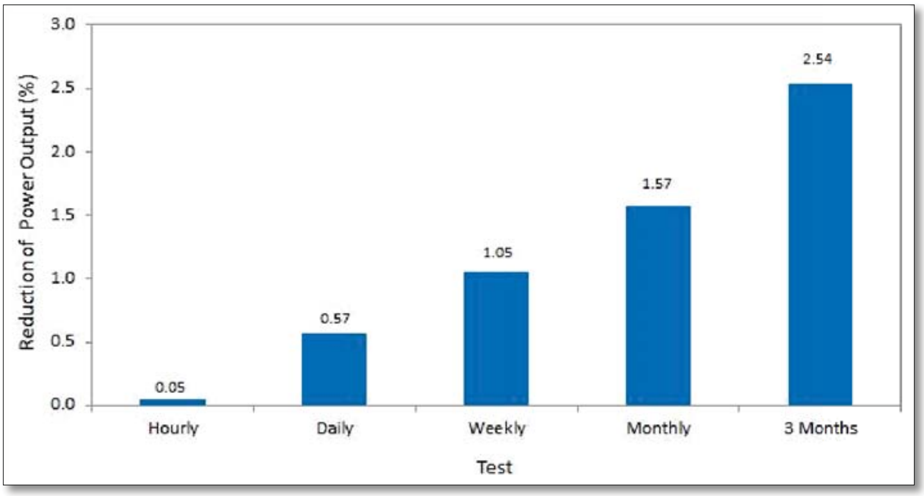


Figure 1.2: Reduction in electrical power output due to dust accumulation for different test durations (Sulaiman et al, 2015)

Since solar panels are placed in environments that are open to the elements, over the course of time, the surfaces of the panels might acquire a layer of dirt, dust, and other particles. This layer of filth lessens the quantity of sunlight that reaches the solar cells, which in turn lowers the amount of energy that is produced by the panel. Cleaning the panels on a regular basis helps eliminate this accumulation, which enables the panels to absorb more sunlight and produce more power.

It is important to ensure that there are no particles on the solar panel that are preventing the irradiance from reaching the solar cell so that the output of the solar cell may be maximized. In order to increase or improve the solar panel's efficiency, it must be cleaned, which is a tiresome task for big solar arrays. To guarantee optimal energy extraction, solar panels must be kept clean by a method that is both efficient and well-managed. It is necessary to have an effective cleaning mechanism to remove these cement-like particles that have accumulated on the solar panel's surface [7].

In a broader sense it is essential to clean solar panels on a consistent basis in order to maximize energy output, increase the lifespan of the panels, and optimize their function. Solar panels may operate at their maximum efficiency once dirt, dust, and other impurities are removed from their surfaces. This results in improved energy outputs as well as a renewable energy source that is more sustainable and cost-effective.

1.2 Problem Statement

The expense associated with the installation and usage of solar panels is one of the biggest obstacles consumers confront. However, the cost may be significantly reduced by increasing the efficiency of each solar panel and, as a result, reducing the number of solar panels necessary for installation. Using lesser photovoltaic panels to supply the necessary quantity of power would not only save money but will also benefit the environment.

To enhance the efficiency of solar panels, two primary factors must be considered: The amount of sunlight that reflects completely on the photovoltaic, and how much of that light energy may be used to generate power. The dust that collects on solar panels is a problem associated with their use.

Dust on the cells of the solar panels significantly affects their efficiency, particularly in open locations where dust is prevalent. Therefore, there will be an automatic system that will routinely clean the solar panels in order to maintain their top performance.

1.3 Objectives

The primary objective of this research is to build a low cost and reliable Solar Panels Automated Cleaning System.

Its measurable objectives are as follows:

i. To investigate the effect of Automated Cleaning System of Solar Panels on energy generation using Arduino microcontroller.

ii. To design and fabricate a prototype for the proposed automated cleaning system of solar panels in order to boost the efficiency by increasing the energy output of solar panels and cost-effective manner using Arduino microcontroller.

iii. To test the performance of the Automated Cleaning System of Solar Panels on detecting the dust accumulation, cleaning the solar panels modules and power output.

1.4 Project Scopes

This project's scope is broken down into two main categories: software development and hardware creation.

This project will conduct with the following steps:

i. Modeling and simulation

- The control algorithm is simulated using Arduino IDE in order to generate the codes and compile the code to check the presence of errors. Subsequently, the code will be uploaded to Arduino UNO.

ii. Hardware implementation

- Design and implementation of the automated cleaning prototype using Arduino controller board as the main control unit, solar panel, Wi-Fi modules, motor modules, dust sensor, DC motors, wiper and battery.

iii. Evaluation and testing of the developed system

- The developed system will be evaluated and tested to ensure that the system is able to properly identify the detection of dust accumulation and maximize the cleaned surface area of solar panels, determine the efficiency of energy generation in solar panel, and to calculate the power output of solar panels.

CHAPTER 2

LITERATURE REVIEW

2.1 Technology Development

The automated cleaning system for solar panels is made up of programmable electrical controllers and sensors that detect dust collection on the surface of the panels and then wash and rinse them. To maintain a high degree of efficiency, the system includes a mechanism that automatically executes clean and wash phases.

2.1.1 Automatic Solar Panel Dust Cleaning with Night Sensing Auto Shutdown

Based on [8] the author proposes automated solar panel dust cleaning with night-sensing auto-shutoff. This project includes a light dependent resistors sensor, a wiper blade unit, and a sprinkler. To detect dust, the light dependent resistors sensor distinguishes between day and night. Dust is observed on the sun's surface depending on the solar power. If dust is detected, the wiper blade and water sprayer start working on the surface. The circuit is governed by an Atmega-328microcontroller. The battery is utilised to store power, which is then provided to the cleaning system. To get the readings from the solar panel and light-dependent resistors into the Atmega328 microcontroller, a voltage divider and an A/D converter are used. An analog-to-digital converter (ADC) takes an analogue voltage and turns it into a digital integer proportionate to its magnitude, whereas a voltage divider is a passive linear circuit that creates an output voltage that is a fraction of the input voltage. During wiper's sweep cycle, this system acquires the surface of the panels. The windscreen wiper is propelled over the panel by a motor. Energy from the sun is stored in a battery and used to power the engine. Unfortunately, while this design may be advantageous for other panels with minimal variations in size, it would require modification for really small panels, such as 40W or 50W, to make its use economically viable.

2.1.2 Design and Construction of an Intelligent Self-Cleaning Solar Panel System

The author builds and develops self-cleaning, Internet of Things (IoT) mobile application-based solar panels in a research project [9]. The proposed method allows one to not only examine the electrical power produced by solar cells, but also provides instructions for cleaning their photovoltaic surfaces. The GP2Y1010AU0F optical air quality sensor is used to identify dust particles which have a diagonally built phototransistor and an infrared emitting diode. This plan will be able to identify dust on the solar panel by averaging the dust reflection. Arduino Uno is a microcontroller that can monitor the power output of a photovoltaic panel in real time and determine how much of an impact dust collecting has on that power. A microprocessor controls the windscreen wiper system through a relay driven by solar energy generated by the solar PV. This windscreen wiper equipment cleans solar panels automatically. The windscreen wiper system consists of a water sprayer and an electric DC control powered by solar panels using a DC-to-DC step-down converter. Thus, when fine particles collect on the solar panel's surface or when encouraged by the IoT application, the solar panel's energy will power the windscreen wipers to operate automatically. The fundamental goal of remote client control is to design or build an application that can respond to certain parameters and is easy to use. Blynx software was used to create the application. In order to give constant data on solar-based modules for voltage output and residual layer intensity, the adaptable application makes use of a Wi-Fi module. In order to activate the cleaning mechanism of a PV module equipped with a wiper, one must press the activity control button. The sole restriction of this study was that the produced system was not anticipated to be used commercially, but rather as a foundational solution for the future creation of numerous applications.

2.1.3 Constructed with a Programmable Logic Control (PLC) Strengthened Self-Cleaning Solar Panels for Greater Efficiency

In addition, the author has come up with an original concept of robust automated solar panel cleaning using a programmable logic controller (PLC) to boost efficiency [10]. This is an external, detachable system that may be configured to clean the solar panel's surface with or without water. It makes sense technically and economically. To clean the panels, it has a set of strong yet gentle nylon brushes, and two squeegees, one on each side of the brush, to soak up the water. The concept is to equip the solar panel with four dust sensors and a set of brush bars. If the solar panel's sensors detect dust, the brush bars will remove it. The solar panel, supply, sensors, pump, water reservoir, water pipe, motor, conveyor belt, brush bars, and water drainage pipe are the ten main parts of the suggested design. Software is required for the PLC-based control circuits that automate the process of removing dust from the surface of solar panels. Possible methods of its production include expanding the DELTA ISPSoft program's ladder logic. Using DELTA DOPSoft, researchers were able to check the logic by simulating the HMI. This HMI model has been thoroughly tested, and all of the blocks appear to be in good working order. Despite this, programmers frequently encountered several difficulties when utilising HMI. This is because the software requires extensive testing, and mistakes will only become apparent after the programme has been executed.

2.1.4 Cleaning Technology for Solar Panels by Texas Instruments of Cloud-Based

The author created and presented a completely automated Internet of Things (IoT)-based solar panel cleaning system based on the research results [11]. The CC3200 first on-chip Wi-Fi microcontroller from Texas Instruments forms the basis of the created system, with sensors for detecting relevant data. In this research, researchers employ the YL-63 rain sensor and the GP2Y1010AU0F dust sensor to track dust and raindrops on a solar panel's surface. The specified microcontroller's built-in Wi-Fi allows it to constantly gather data from the interfaced sensors and send it to the Thing Speak Cloud. On an Android phone, the data may be viewed and tracked in real time. A servo motor linked to the relay system regulates the speed and rotation of the windscreen wipers. Through the use of GeoTagging, the precise location of debris-strewn solar panels can be monitored, and an alert may be sent to the user via the GSM module. The results demonstrate that after cleaning, the current generation and maximum power of the solar panels are increased by 50% using the IoT-based kit that was built. Regrettably, the programme not available for non-Android users, despite the system's straightforward design and inexpensive components.

2.1.5 An Automatic Dust-Free Solar Panel Cleaning System Powered by Arduino

In another study [12], the authors built and executed an Arduino-based dust-removal system for solar panel cleaning. The ideal system for maintaining solar panels requires just inexpensive, readily available materials. The primary components include a solar panel that produces dc electricity, a microcontroller which is Arduino Uno, a metallic dc gear motor, a buck boost converter that accepts input from the solar panel and maintains a constant voltage supply, and a motor drive module that drives the motor using the solar dc energy. The system's design allows it to start functioning as soon as the microcontroller and LDR sensor detect the value of the sun. This is an automatic cleaning system since LDR sensors are used. The suggested technology uses sunshine monitoring to kick on the panels even when there are no particles on the surface. The best way to clean solar panels is using an automated system that still does not require the use of water. There is an exhaust fan that blows air over the panel, and there is also a wiper that clears the surface of dust. A direct current motor drives the wiper. Reduces water waste and might work in places without a reliable water supply because solar panels are not submerged in water during the cleaning process. Therefore, the suggested technique is effective for various sorts of dust. Various varieties of sand may be cleaned with an effectiveness ranging from 87 to 96 percent, as demonstrated by the experimental findings. Even while dust exposure can be reduced by applying the system, it may not be able to make accurate predictions when there is a large amount of dust variation. However, the issue may be resolved in the near future with the aid of improved technology and critical thought.

2.1.6 Illustration of Automatic Panel Cleaning System

In a different study, the author [13] presented an automated panel cleaning system that employs Artificial Intelligence and Computer Vision to avoid soiling, therefore enhancing the performance of solar technologies. Utilize a drone equipped with an above camera to monitor the solar panels and an end effector to do the cleaning procedure. The collected image is then analysed by Machine Vision algorithms to determine the kind of soiling, prompting the drone to remove the contaminated particles. The data set stored in the ground subsystem must be categorised in order to extract the distinct picture patterns.

This is accomplished by utilising the CNN algorithm, since Convoluted Neural Networks offer extremely efficient, dependable, and speedier results. The drone is equipped with a thermal camera, which greatly assists in identifying hotspots, cracks, and transitory shadowing issues such as dust and bird droppings on the panel. The link between the thermal camera and the subsystem on the ground provides the coordinates of panel flaws, allowing the panels to be cleaned. Attached to the drone are end effectors consisting of blowers to blow away dust, vacuum suction to remove bird droppings, and brushes with sponge to clean any other filthy particles. On top of the drone is a spray tank that is controlled by a spray block control system. Through constant monitoring of real-time data, the drone is able to remove dirty particles. The drone can hover around the whole length of the panel and function without interruption. Moreover, with the use of Artificial Intelligence and Computer Vision, the author is also able to make valuable conclusions regarding the influence of various elements on soiling, and these predictions would be useful for implementing preventative and remedial actions. The sole disadvantage of the method is the selection of a big dataset for training the model and, consequently, getting accurate predictions for each input sample.

2.1.7 Arduino-Based Solar Panels Cleaning Robot Development

The author builds and creates an Arduino-based robot for the autonomous cleaning of solar panel surfaces with and without water based on the study [14]. Components include a microcontroller unit, battery, ultrasonic sensor, two-wheel-drive (WD) chassis with DC motor, water pump, water tank, brushes, and water. During the cleaning process, an ultrasonic sensor sends data to an Arduino controller system, which then directs the robot's movement. It also controls the rate at which water is pumped to the brushes during washing. The distance covered by the proposed robot during its movements is gauged in this way apparently to an ultrasonic sensor. The robot's in-built cleaning system comprises of front and rear static brushes, a water pump, and a water tank. A specialized water pump draws water from the tanks and pumps it to the brushes at a high enough pressure to remove dust and debris from the PV panels. When activated, the robot will spin at a rate of one hundred times per minute. The ultrasonic range finder is also activated and will now track the robot's progress in terms of distance. Any forward progress by the robot beyond 5 centimeters is met by an immediate and gradual reversal of its forward momentum. When the microcontroller's lag time goes beyond 1 second, the robot reverses direction. The route stays straight for some time after that. Every time the robot is restarted, this process is carried out again. In addition, the efficiency of the PV panels is measured both before and after they have been cleaned. It has been shown that after cleaning the dust from the PV panel, the output current and maximum power of the panel can be increased by 50 percent of the overall using the newly developed solar panel cleaning robot. Unfortunately, the robot's walking route may be programmed inefficiently to clean all of the solar panels if the method is used to a larger array of solar panels.

2.1.8 Photovoltaic (PV) Panels Cleaning Programs Incorporate an Autonomous Adaptable, Low-Power Industrial IoT Controller

In this paper, the author designs the infrastructure for an autonomous, low-power, Industrial Internet of Things (IoT) device with a particular emphasis on photovoltaic solar panel cleaning [15]. The control system may connect to the internet through LAN or WLAN, monitor the position and all system parameters, and control the drives of the movement motor and brush motor all while running a Debian-based Linux distribution. Furthermore, with the Arduino UNO and L293D connected to a geared motor, conveyor belt, pulley, and wiper, the controller may be linked to SCADA frameworks through Modbus TCP for relaying data and monitoring in fully functional solar power plants. Limitation of this system is even though the system proposed is beneficial in minimizing the aftereffects of dust accumulation, the design itself is rather complex as SCADA frameworks comes with a lot of features and configuration that is difficult for the developers to understand.

2.1.9 Solar Panel Cleaning System Design and Manufacturing

In the research [16], the author builds an autonomous cleaning robot in order to boost the efficiency of power generation, which requires routine module cleaning. To remove the dust, an autonomous cleaning robot is designed to clean the panels at predetermined intervals. The invention employs a timer circuit in the machine that allows the user to decide how many times per day the machine should clean the solar panels. The circuit consists of simply three buttons; one will start the machine, while the other two will raise and decrease the displayed time in seconds. A limit switch on both ends of the machine stops the machine when it reaches the end of the solar panel row. For the purpose of cleaning the panels, a control circuit, a DC motor, and microfiber brushes are utilised. The only limitation in the system it can include highly intriguing features such as deionized water cleaning, an inspection camera, and climate-based cleaning.

2.1.10 The Design and Construction of an Automatic Dust Cleaning System for Solar Panels Based on a Microcontroller

The research [17] compels the author to build and implement an autonomous solar panel dust cleaning technology. The developed automated cleaning system comprises of a combination of IR LEDs and photo diodes to detect dust on the solar panel. If there is dust on the panel, then the quantity of infrared rays that are constantly falling on the panel and that are reflected back to the photo diode will be lowered. This will cause the output of the sensor to rise, and these signals will then be communicated to the microcontroller. The input signals are compared by the controller with the data that has been preprogrammed for the movement of the motor. The controller then drives the motor driving circuit to spin the motor in the desired direction, either clockwise or anticlockwise, depending on the input signal. The wiper is coupled to a motor that rotates in both clockwise and anticlockwise directions. Therefore, the cleaning is performed. The efficiency of a solar panel may be estimated by comparing the panel's voltage and current output before and after being exposed to dust for numerous days, weeks, or months. Using the collected information, a comparison of the performance of solar panels with and without dust is carried out. The proposed automated cleaning technology offers an efficient, nonabrasive cleaning and prevents power generation anomalies caused by dust accumulation on the solar panel. Regular cleaning raises the average efficiency of solar panels by 1.6% to 2.2%, according to the research. Consequently, created models increase productivity since system relies heavily on the availability of an input signal that is responsible for forwarding the information collected to the server for processing.

2.2 Research gap

Table 2.1 represents the summary of different research related to the title of this project which is IoT-Based Solar Panels Automated Cleaning System using Arduino Microcontroller. By referring to the table, there are several methods suggested by the authors together with the outcomes of the research and its limitations.

Table 2.1: Summary of previous research

Author (s)	Year	Methods	Outcome of Research	Limitations
Rathod Y, Bhavsar M, Jadhav M, Shah J, Bawle M, Sameer M, Sontakke T, Kumthekar R	2018	The LDR sensor is used to distinguish between day and night and to detect dust.	• The circuit is governed by an Atmega-328microcontroller. • If dust is identified, the wiper and water sprayer begin to operate on the surface.	Modifications to the system are going to be necessary in order to enable the utilisation of extremely tiny panels with outputs of 40W or 50W economically viable
Zainuddin N, Mohammed M, Al-Zubaidi S, Khogali S	2019	It is a self-cleaning system with Internet of Things (IoT) mobile application based solar panel.	• The approach will use the average dust reflection to identify dust surrounding the solar panel's surface. • Microcontroller Arduino Uno is used to gauge the photovoltaic (PV)	It was not envisaged that the system would be utilized commercially, but rather as a fundamental solution enabling the building of

			panel's output and analyses the influence of dust deposition on the output power in real time. • Blynx software to trigger a motor wiper's activity control.	future applications.
Mandal M, Jena C, Sinha P, Jena T, Roy S	2021	It is a robust automated solar panel cleaning system that is based on programmable logic controllers (PLCs), with the aim of increasing efficiency.	• When the sensors are triggered, the solar panels are cleaned thoroughly by brush bars to which sweep the dust away from the surface. • PLC-based control circuits that are used to clean automatically need software. • It is possible to create it with the DELTA ISPSoft application by using the ladder logic design tool.	Programmers frequently encountered several difficulties when utilising HMI. This is because the software requires extensive testing, and mistakes will only become apparent after the programme has been executed.

Supriya K, Sundar C, Vani P	2022	Encompassing Wi-Fi, the Internet of Things-based solar panel cleaning system continually captures and uploads sensor data to the Thing Speak Cloud.	• The YL-63 rain sensor and the GP2Y1010AU0F dust sensor are used to monitor the dust and precipitation levels on a solar panel's surface. • The system consists of sensors for detecting the required parameters and the first on-chip Wi-Fi CPU from Texas Instruments, the CC3200. The information may be seen and tracked in real-time on an Android smartphone	The programme is not available for non-Android users.
Alam S, Shawmee T, Ahmed K, Alrashed A, Habib M, Tanvir M, Suhan A, Vadher A	2021	It is a dust-removal device for solar panels built on the Arduino platform, and it monitors the sun to kick	• Both the microcontroller and the light-dependent resistor (LDR) sensor are programmed to detect this value when daylight arrives	The system may not be able to make accurate predictions when there is a large amount of dust variation.

		into gear even when there are no dust particles on the panel surface.	• LDR sensors are utilised, making this an automated cleaning system	
Prasad A, Professor A	2020	It is an automated panel cleaning system that employs Artificial Intelligence and Computer Vision to avoid soiling while enhancing the performance of solar technologies	• System utilizes a drone that equipped with an above camera to monitor the solar panels and an end effector to do the cleaning procedure. • The collected image is then analysed by Machine Vision algorithms to determine the kind of soiling, prompting the drone to remove the contaminated particles.	The selection of a big dataset for training the model and consequently, getting accurate predictions for each input sample.
Noh F, Yaakub M, Nordin I, Sahari N, Zambri N, Yi S, Saibon M.	2020	It is an Arduino-based robot for the automatic cleaning of solar panel	• During the cleaning process, the ultrasonic sensor sends data to an Arduino controller system, which then	Testing the method on a larger collection of solar panels may prevent it from reaching

		surfaces with and without water.	directs the robot's movements. • An ultrasonic sensor monitors the proposed robot's moving distance. • The cleaning robot moves forward at a certain distance and reverses when it reaches a certain time delay.	its maximum cleaning potential.
Tranca D, Rosner D, Palacean A	2017	Industrial Internet of Things (IoT) controller with Linux distribution based on Debian that is dedicated to cleaning PV solar panels.	• Connectivity options include local area network (LAN) and wireless local area network (Wi-Fi), with the system being able to operate all motors for movement and monitoring its position and attributes. • Using Modbus TCP for data transport and control via Arduino UNO, solar plant controllers may be synchronized with	The design itself is rather complex as SCADA frameworks comes with a lot of features and configuration that is difficult for the developers to understand.

			SCADA frameworks	
Wable S, Ganiger S	2017	An autonomous cleaning robot that requires routine module cleaning where it is designed to clean the panels at predetermined intervals to remove the dust.	• The technology uses a timer circuit in the machine that allows the user to specify the number of times per day that the machine will clean the solar panels. • The system cleans the panels is based on a control circuit, DC motor, and microfiber bristles.	It can include highly intriguing features such as deionized water cleaning, an inspection camera, and climate-based cleaning.
Patil S, HM M	2016	The developed automated cleaning system comprises of a combination of IR LEDs and photo diodes to detect dust photovoltaic panels.	• The output of the sensor rises as signals are sent to the microcontroller as dust on the panel limits the amount of constantly falling IR rays that are reflected to the photo diode. • The controller compares inputs from the motor's sensors with stored information to	The productivity the system is that it relies heavily on the availability of the input signal that is responsible for forwarding the information collected to

			determine whether or not to move, and then commands the motor's drive circuit to spin the motor so that it may be cleaned	the server for processing

Therefore, in order to create a flexible detection and environmental monitoring system at a cheap cost, this research will adopt the method that was developed by Supriya K et al [11], as it is now accessible. The manual mode was also added to the system, allowing users to exercise control over it regardless of where they are. In order to improve the efficiency of the automatic cleaning system for solar panels, an efficient cleaning procedure that requires only the barest minimum of supplies, such as water or brushes, should be carried out whenever it is necessary.

2.3 Summary

This chapter provides a summary of the numerous studies and research that are relevant to the project's title. Some of the studies and research are being used in this project as references for the purpose of accomplishing this project. The project will employ the approach that was created by Supriya K et al [11] and it will use an Internet of Things-based cleaning system for solar panels. This system will feature automatic cleaning, monitoring, and control of the system.

CHAPTER 3

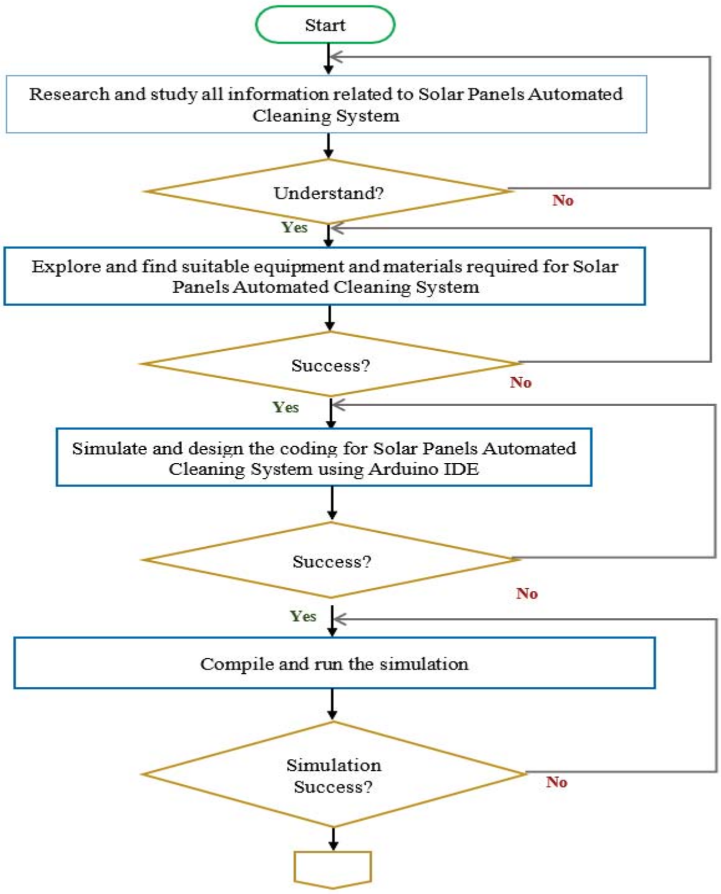
METHODOLOGY

3.1 Introduction

This chapter explains the rationale behind the suggested research strategy and project idea for an IoT-Based Solar Panels Automated Cleaning System using Arduino Microcontroller. The equipment, materials, and components have also been chosen.

3.2 Project Plan

Figure 3.1 shows the flow chart of the proposed IoT- Based Solar Panels Automated Cleaning System by using Arduino UNO.



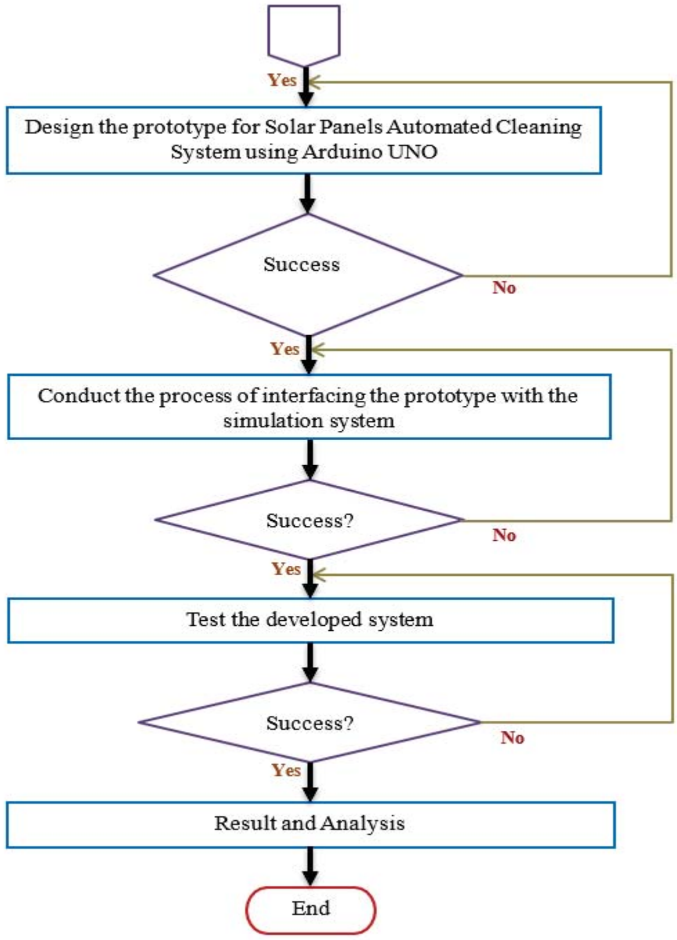


Figure 3.1: Flow chart for proposed IoT-Based Solar Panels Automated Cleaning System using Arduino UNO

All information on Solar Panels Automated Cleaning was examined and analyzed at the outset of the project, based on the preceding diagram. Once the information was comprehended, the project was proceeded by investigating and locating the necessary equipment and supplies for the system. If this stage was completed successfully, the system's code will be developed and simulated with Arduino IDE. Nevertheless, more study will be undertaken if it is unsuccessful. The simulation was then compiled and executed to check for programming faults. After ensuring that the simulation was error-free, a prototype of the suggested system would be created. The procedure of integrating the prototype with the simulation system could not be carried out until the prototype was complete. The constructed system was then tested to confirm its functionality, after which observations can be made. If the system were error-free, results and analysis might be generated. However, the testing procedure would be repeated if difficulties were discovered. Finally, the project would be deemed complete after all of these procedures have been properly executed. If not, the preceding procedures would be revised and repeated.

3.3 Block Diagram

The block diagram of the proposed IoT-Based Solar Panels Automated Cleaning System using Arduino Microcontroller is presented in Figure 3.2.

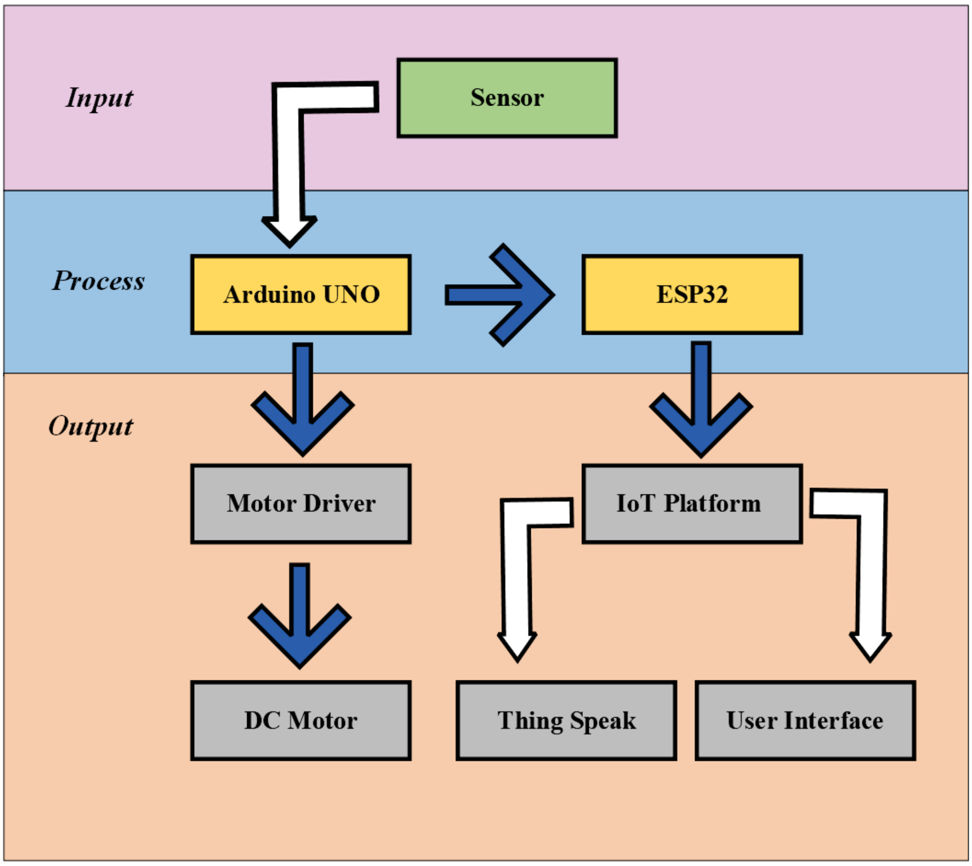


Figure 3.2: Block diagram of IoT-Based Solar Panels Automated Cleaning System using Arduino Microcontroller

Throughout of this project, an IoT–based automatic cleaning system for solar panels using microcontroller will be developed. The Arduino UNO serves as the primary control unit for this system. It is responsible for receiving signals from various sensors and adjusting the operation of the appliances accordingly. After that, the data is sent to the motor driver, which is the component that ultimately controls the DC motor. In addition, data is transmitted from the Arduino UNO via the ESP32, which is a Wi-Fi module that makes it possible for the Internet of Things platform to operate by utilising the

ThingSpeak software. Users are able to keep track of the amount of time that the solar panels have been operational before they need to be cleaned. In addition to this, the system includes a user interface, which gives consumers the ability to manually operate the cleaning system from any location using the cloud.

3.4 Conceptual Design

The conceptual design of the proposed IoT-Based Solar Panels Automated Cleaning System using Arduino UNO is presented in Figure 3.3.

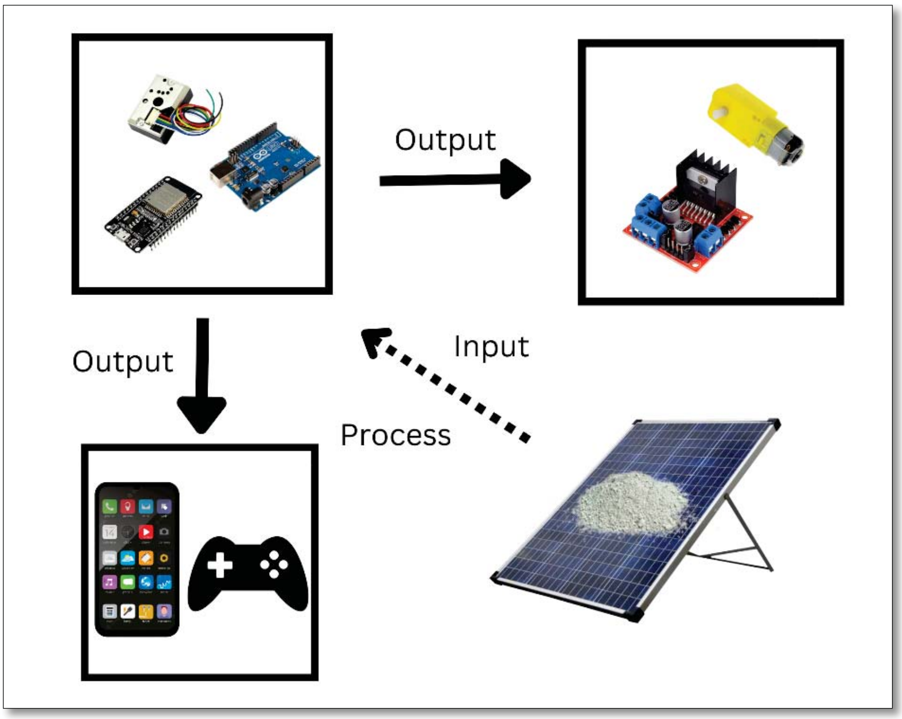


Figure 3.3: Conceptual design of IoT-Based Solar Panels Automated Cleaning System using Arduino Microcontroller

The system that has been proposed is made up of three basic components. The first part of this system comprises sensing and analysing the density of the dust, with the data being outputted over an Internet of Things platform when the recorded dust density reaches a certain threshold. The second component is a windscreen wiper system that is actuated by a signal sent from a microcontroller through a motor module. This happens when the threshold is reached. The solar panels' cleaning system is controlled by the third element, which is responsible for its overall operation. Using an Internet of Things application, it is possible to apply remote control over this system via the cloud.

Analysing the information gathered from sensors and the microcontroller in dusty conditions is the primary subject of this study, which was designed to investigate the effect that accumulated dust has on the performance of solar panels. In addition to this, a windscreen wiper system that cleans itself automatically is utilised so that the flat solar panels can be maintained in a clean state.

3.5 Equipment and Materials

The equipment and materials applied for developing and stimulating the IoT-Based Solar Panels Automated Cleaning System using Arduino microcontroller can be divided into two types which are the software and hardware.

3.6 Software Used

Software is an integral component of contemporary technology, functioning as the link between users and electronic devices. It encompasses a vast array of applications, ranging from operating systems that manage hardware and provide essential services to specialised programmes designed for particular duties, such as word processing, web browsing, and gaming. Utility software aides in system administration, whereas device drivers facilitate communication with peripheral hardware.

3.6.1 Fritzing

Figure 3.4: Icon for Fritzing[18]

The Fritzing programme is an open-source software endeavour with the goal of developing hobby CAD software for the design of electrical hardware beginning with the experimentation of a prototype in order to produce a circuit that is more permanent[19]. In this automated cleaning system, Fritzing is utilised as the primary tool for designing the initial version of the cleaning system. Before beginning construction on the overall permanent circuit, each and every connection of sensor and component is carefully planned and wired. This is done in order to ensure that the circuit has been thoughtfully planned and is correctly linked. As a result, it lowers or gets rid of the amount of connection failures in the circuit.

3.6.2 Arduino IDE

Figure 3.5: Icon for Arduino IDE[20]

Programming with Arduino may be done on a platform known as Arduino IDE, which stands for Integrated Development Environment. It is utilised to develop, compile, and upload the codes or programmes to Arduino compatible boards, such as Arduino UNO, Arduino Mega, Arduino Nano, and other Arduino boards[21]. Additionally, it is compatible with connecting to other boards, such as the ESP32 Wi-Fi Module. This piece of software offers support for the C programming language in addition to C++, and it makes use of code structure. As a result, the software known as Arduino IDE is being used to write code for an automatic cleaning system for solar panels, and then that code is being transferred to an Arduino UNO board.

3.6.3 ThingSpeak

Figure 3.6: Icon for ThingSpeak[22]

ThingSpeak is a service that operates as an IoT analytics platform. It is utilised for collecting, visualising, and doing analysis on the live data streams that are stored in the cloud[23]. In addition to that, it may be used to store data and retrieve it using HTTP when connected to the internet. In addition to this, it generates quick visualisations of live data and allows users to get warnings whenever it is essential to do so. In addition, MATLAB code may be utilised in this programme to carry out pre-processing, visualisations, and statistical analysis. Using ThingSpeak, one is able to build sensor logging apps, position tracking applications, and social networks of things with status updates. Users are able to prototype and create Internet of Things systems using ThingSpeak, which is an excellent piece of software that does not require the setting up of any servers.

3.6.4 Blynk

Figure 3.7: Icon for Blynk[24]

Blynk applications provide a nice user interface that enables users to remotely control and monitor hardware devices like as Arduino, Raspberry Pi, and ESP32 using a mobile device or tablet. These devices may be controlled and monitored using Blynk. Users are able to quickly and simply design their own mobile applications with the help of Blynk by dragging and dropping widgets into a bespoke control panel[25]. The usage of these applications enables users to interact with linked devices, transmit commands, get real-time data, and visualise sensor readings, which makes the management of Internet of Things (IoT) projects simple and comfortable. Thus, it can be used for automated cleaning system of solar panels project.

3.7 Hardware Used

Hardware's purpose is to provide the tangible components and infrastructure required for computers and electronic devices to effectively process data, execute tasks, and interact with users. This includes the central processing unit for processing information, storage devices for data retention, input and output devices for user interaction, networking hardware for connectivity, graphics rendering, power supplies for stable electricity, expansion slots for component upgrades and peripherals for extended functionality. Hardware provides the essential foundation for software to function and enables digital devices to conduct a vast array of tasks.

3.7.1 Solar Panels

Figure 3.8: Solar Panels[26]

A solar panel as shown in Figure 3.8 is composed of silicon or other semiconductor-based photovoltaic cells. By absorbing sunlight, the photovoltaic cells of a solar panel will collect energy and transmit it to semiconductors. The semiconductor will then generate an electrical field that will provide the current and voltage, so establishing a power source. In order to maximise their efficiency, solar cells are sometimes grouped together in enormous configurations known as arrays [27]. These arrays, made up of hundreds upon thousands of individual cells, may act as central electric power stations, harnessing the sun's rays and transforming them into electricity for usage by businesses, homes, and other institutions. In this system, the solar panels are used to measure their output of power. The specification of solar panels that is used in this project are shown in Table 3.1.

Table 3.1: Specification of Solar Panels[28]

Parameters	Specification
Peak Power (Pmax)	30
Production Tolerance (%)	3
Maximum Power Current (Imp)	1.67
Maximum Power Voltage (Vmp)	18.00
Short Circuit Current (Isc)	1.82
Open Circuit Voltage (Voc)	22.30

3.7.2 Arduino UNO

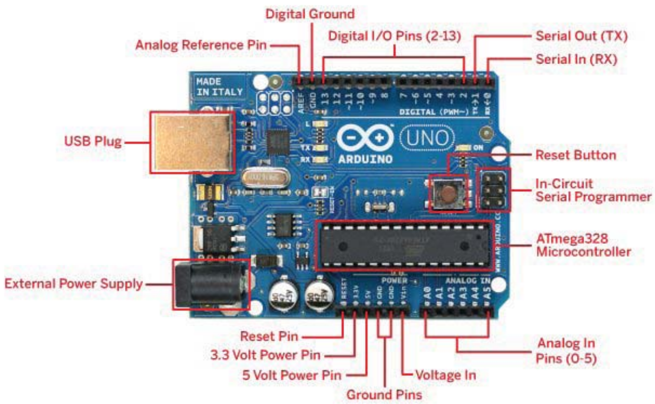


Figure 3.9: Arduino UNO [29]

The ATmega328P is the basis of the Arduino UNO, a microcontroller board, as seen in Figure 3.9. It has 14 digital output and input pins, 6 analogue inputs, a CSTCE16M0V53-R0 ceramic resonator, a power connector, a reset button, a USB port, and an ICSP header. Six input and output pins are available for usage as PWM outputs. The microcontroller may be powered by connecting the board to a computer through USB or by using a battery or AC-to-DC converter. An external power supply ranging from 6 to 20V can be used to power the Arduino UNO [30]. Despite this, if the power supplied is less than 7V, the board may become unstable, as the 5V pin can only provide voltages lower than 5V. If a voltage greater than 12 V is supplied, the voltage regulator may overheat and harm the board. As a result, a voltage range of 7 to 12 V is ideal. Also, the

Atmega328 has 32 kilobytes (kB) of flash memory for program storage, with 0.5 kB set aside for the bootloader. Moreover, it has 1kB of EEPROM and 2kB of SRAM [31]

Table 3.2: Specification of Arduino UNO[31]

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage	7V-12V
Digital I/O Pins	14
Analog Input Pins	6
DC Current I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 MHz

3.7.3 Dust Sensor

Figure 3.10: Dust Sensor[32]

Figure 3.10 illustrates a GP2Y1010AU0F dust sensor that detects dust via optical sensing. The dust sensor module has a photosensor and an infrared light-emitting diode (IR LED) in an optical configuration. The IR LED rays generated by dust particles in the air are picked up by the photo-sensor (PT). It makes use of cutting-edge sensing technology such as infrared LED, optics, a photodiode detector, and an electromagnetic shield. It features a quick sensor-to-microcontroller response time and is sensitive to dust[33]. This sensor may be built with a simple hardware design, as it only requires three wires (VCC, GND, and signal) to communicate with the microcontroller. This makes utilizing an Arduino very accessible to those with little experience in electronics.

Table 3.3: Specification of Dust Sensor[34]

Optical Dust Sensor	GP2Y1010AU0F
Low Current Consumption	20mA max
Typical Operating Voltage	4.5V - 5.5V
Minimum Detectable Dust Size	0.5µm
Dust Density Sensing Range	Up to 580 $\mu g/m^3$
Sensing Time	Less than 1 Second
Sensitivity	0.5 V/(100 $\mu g/m^3$)
Operating Temperature	-10 C to +65 C
Dimensions	1.81 x 1.18 x 0.69" (46.0 x 30.0 x 17.6 mm)

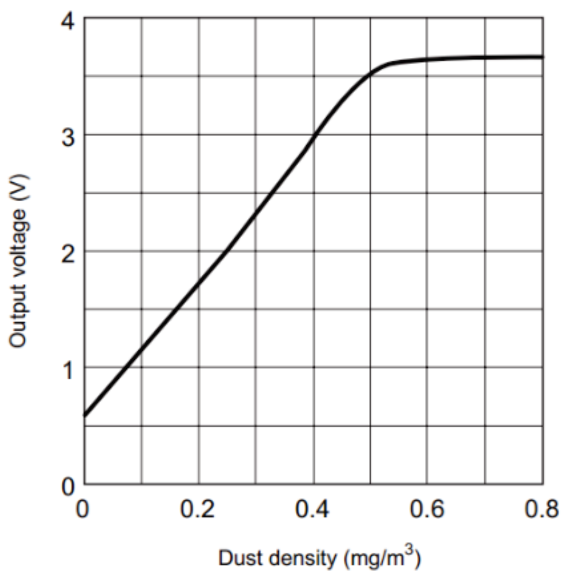


Figure 3.11: Dust Sensor Characteristic[35]

3.7.4 Motor Modules

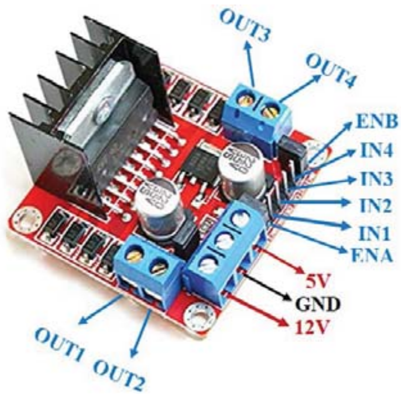


Figure 3.12: Motor Driver Modules[36]

The L298N, shown in Figure 3.12, is likewise a dual H-Bridge motor driver, allowing for the independent speed and direction control of two DC motors. This motor module can provide DC motors with voltages between 5 and 35 volts and a peak current of up to 2 amperes. It is containing a Ground pin, a VCC for motor pin, an input/output 5V pin, and screw terminal blocks for each. Additionally, for motors A and B, the module provides two sets of screw terminal blocks. The VCC supply voltage of the motor will affect this. A jumper gives users the ability to turn on or turn off the 5V regulator that is included in the module. The 5V regulator can be activated and the 5V output pin used to power an Arduino board, for example, if the voltage from the motor supply is at least 12V [37].This would be the case if the voltage was up to 12V. However, if the motor voltage is higher than 12V, it is necessary to unhook the jumper since values of this magnitude would damage the 5V regulator that is integrated into the motor.

Table 3.4: Specification of Motor Modules[36]

Driver Model	L298N
Driver Chip	Double H Bridge L298N
Motor Supply Voltage (Maximum)	46V
Motor Supply Current (Maximum)	2A
Logic Voltage	5V
Driver Voltage	5V-35V
Driver Current	2A

Logical Current	0mA-36mA
Maximum Power (W)	25W

3.7.5 DC Motor

Figure 3.13: Dual Shaft DC Motor [38]

Dual shaft DC motors convert electrical energy into mechanical rotation as their primary function. By supplying the motor with the proper voltage and current, it can control the rotational speed and direction of each shaft. The motor can rotate both clockwise and anticlockwise due to its independent pulleys[39]. This characteristic enables bidirectional control and facilitates applications requiring reversible rotation. The voltage range within which the motor is designed to operate is 3V to 9V. The rated voltage is 6V, which indicates that for optimal performance, it is recommended to operate the motor at this voltage. The speed of the motor is specified as 200 RPM (Rotations Per Minute) at 6V. This represents the rotational speed of the output shafts of the motor under normal operating conditions.

Table 3.5: Specification of Dual Shaft DC Motor [38]

Operating Voltage	3V-9V
Speed	200 rpm
Torque	0.8kg/cm
Ampere	0.3A
Gear ratio	1:48

3.7.6 Wi-Fi Modules

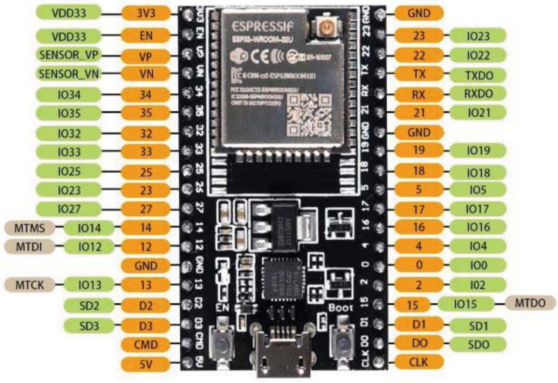


Figure 3.14: ESP32 Wi-Fi Modules [40]

The dual-core Tensilica LX6 processor of the ESP32 enables multitasking and the efficient execution of tasks. It supports 2.4 GHz Wi-Fi networks, allowing the projects to connect to the internet and communicate with other devices and cloud services[41]. It provides a large number of General-Purpose Input/Output (GPIO) ports, enabling to connect and control a variety of sensors, actuators, and other peripheral devices. The ESP32 provides a number of analogue input ports for reading analogue sensor values such as temperature, light intensity, etc. It typically includes variable quantities of Flash memory (up to 4 MB) for programme storage and RAM (up to 520 KB) for data storage and execution. The ESP32 is compatible with both the Arduino development environment. The low power consumption of the ESP32 makes it appropriate for battery-powered applications. Using IoT technology, this Wi-Fi module is used in this project to interface an automated solar panel cleansing system. Thus, users can readily monitor the condition of solar panels using their mobile phones.

Table 3.6: Specification of ESP32 Wi-Fi Modules [42]

Operating Voltage	2.2V-3.6V
GPI/O	36 ports
ADC	14 ports
DAC	2 ports
Wi-Fi	2.4 GHz
Clock Speed	Up to 240 MHz

3.7.7 Rechargeable Battery

Figure 3.15: Rechargeable Battery [43]

In principle, a rechargeable battery may be described as an energy storage device that can be recharged by providing DC current to its terminal [44]. Once the equipment has been completely drained, the process of recharging will conclude. Not only may the rechargeable battery save money and decrease waste since it can be used for an extended period of time, but it also permits numerous uses from a single cell. Despite the fact that this sort of battery requires anode consumption and performs the same duties as a standard battery, the pace of anode consumption is considerably slower. Consequently, it enables repeated charging and discharging procedures. Recharging a rechargeable battery is as simple as inserting the battery in a charger or connecting it to an AC/DC adaptor.

3.7.8 Jumper Wires

Figure 3.16: Jumper Wires [45]

The jumper wires shown in Figure 3.16 are only cables with connection pins at either end. These pins provide the connection of wires between two points without soldering. On a breadboard, jumper wires are typically employed so that the circuit may be altered with relative ease [46]. There are essentially three categories of jumper wires: male-to-male, male-to-female, and female-to-female. Male-to-male jumper wires are the most common. The three ends of these wires are the only thing that set them apart from one another. A male end will have a protruding pin that can connect to other things in the environment. On the other hand, a female end is normally what is utilized in order to plug things into.

3.7.9 Breadboard

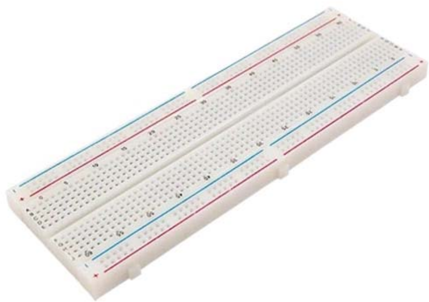


Figure 3.17: Breadboard [47]

Figure 3.17 is an illustration of a breadboard. It is regarded as a solderless device for electrical and test circuit prototypes. Breadboards allow for the interconnection of electrical components in circuits by putting the terminals of devices or components into the holes. The connections are then made using wires wherever necessary. In addition, metal strips are located beneath the breadboard. The holes on the board's top and bottom rows are connected horizontally, while the holes in the board's middle section are connected vertically.

3.7.10 Windscreen Wiper

Figure 3.18: Windscreen Wiper [48]

The blade of the windscreen wiper is made of rubber or silicone and slides across the surface of the solar panel in a manner that is analogous to that of the wipers used on vehicles. The blade, as it moves, removes any dirt, dust, leaves, or other contaminants that may have settled on the panel. It does this by sweeping them away as it moves. It is possible that the efficiency of a solar panel will suffer dramatically if it is covered in dirt or other particles. The existence of particles from other realms decreases the amount of sunlight that is able to reach the solar cells, which in turn limits the solar cells' capacity to create power. It is possible to maintain optimal sunlight exposure and maximise energy generation by cleaning the panel with a windscreen wiper. This helps keep the panel in good condition. There is a wide variety of solar panel types and sizes that windscreen wipers can be made to accommodate. They can be put on either fixed-mount or tracking systems, which ensures that they will perform effectively independent of the orientation of the panel or the tilt angle.

3.8 Hardware Connections

3.8.1 Dust Sensor Connections

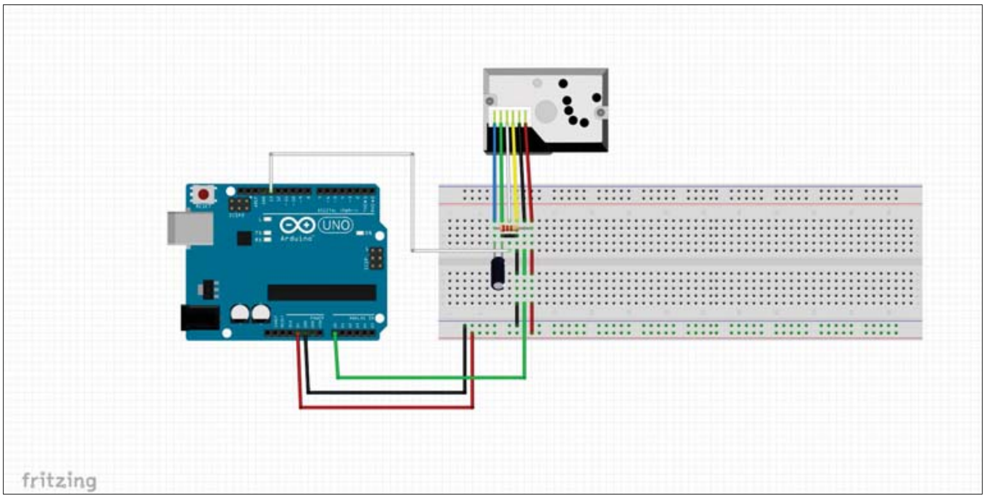


Figure 3.19: Connection for Dust Sensor

Utilise the ADC of the Arduino board in order to transform the data and compute it into a value that is understandable for the dust sensor connection. The LED enable pin of the sensor needs to be connected to one of the GPIO pins of the Arduino. The white wire needs to be connected to the D13 pin on the Arduino. After that, it is also necessary to connect the LED enable pin of the sensor to one of the GPIO pins of the Arduino. In addition to that, it requires a resistor of 150R and a capacitor of 220uF. The resistor and the capacitor together make up an RC timer circuit, which in this instance is a pulse driver circuit. This circuit is required for the device to operate in a stable manner, and the datasheet provides values that are suggested for use.

Table 3.7: Pins Connection for Dust Sensor

Dust Sensor	Connected to Arduino UNO
Vcc	5V
Vout	A0
GND	GND
LED	Pin 13
LED-GND	GND
V-LED	Connect to Arduino's 5V OUT via 150-ohm resistor

3.8.2 L298N Motor Driver Module Connections

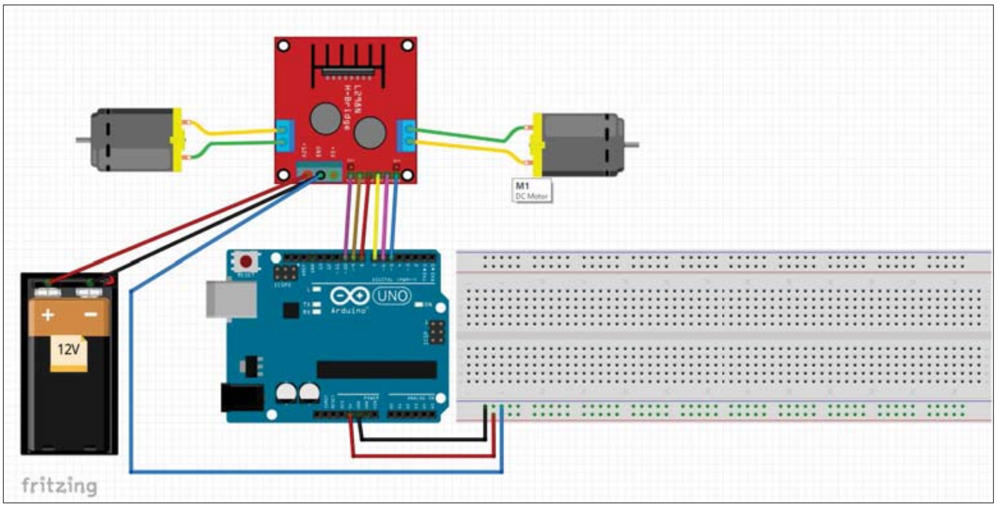


Figure 3.20: Connection for L298N Motor Driver Modules

For motor driver module connection, connect the Vs terminal to an external power source that provides 12 V. The motors will get 10 V and spin at a rate that is somewhat slower due to the voltage drop that L298N causes, which is around 2 V. The following procedure is to make sure that the logic circuitry of the L298N is receiving 5V. The next step is to pull 5V from the motor power supply using the on-board 5V regulator while maintaining the position of the 5V-EN jumper. At this point connect the Input and Enable pins of the L298N module (ENA, IN1, IN2, IN3, IN4, and ENB) to the six digital output pins of the Arduino (5,6,7,8,9, and 10). Consider that the PWM function may be accessed on both the Arduino output pins 5 and 10. In the end, it will need to connect one motor to terminal A (OUT1 and OUT2) and the other motor to terminal B (OUT3 and OUT4).

Table 3.8: Pin Connection for L298N Motor Driver Modules

Motor driver module	Connected to Arduino UNO
ENA	Pin10
IN1	Pin 9
IN2	Pin 8
IN3	Pin 7
IN4	Pin 6
ENB	Pin5
GND	GND

Motor driver module	Connected to DC motor
OUT1	Anode (+ve)
OUT2	Cathode (-ve)
OUT3	Anode (+ve)
OUT4	Cathode (-ve)

Motor driver module	Connected to battery
12V	Anode (+ve)
GND	Cathode (-ve)

3.8.3 ESP32 Wi-Fi Modules

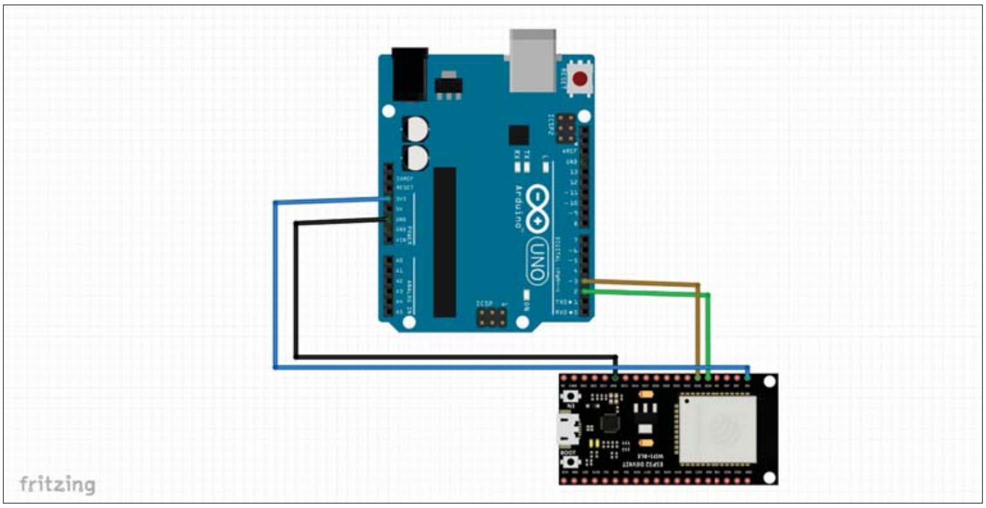


Figure 3.21: Connection for ESP32 Wi-Fi Modules

Connecting an ESP32 Wi-Fi module to an Arduino UNO board is required in order to control over the system via mobile applications. Figure 3.21 depicts the connection diagram that should be used when attaching the ESP32 Wi-Fi module to the Arduino UNO. On the other hand, RX35 is linked to the TX3 pin, while RX2 is attached to the TX34 pin. This Wi-Fi module gets its power from a source that is 3.3V, not 5V. The pin connections for attaching an ESP32 Wi-Fi module to an Arduino UNO are detailed in Table 3.9.

Table 3.9: Pin Connection for ESP32 Wi-Fi Modules

ESP32 Wi-Fi module	Connected to Arduino UNO
TX34	RX2
RX35	TX3
GND	GND
3V3	3V3

3.9 Schematic Diagram of Automated Cleaning System Solar Panels

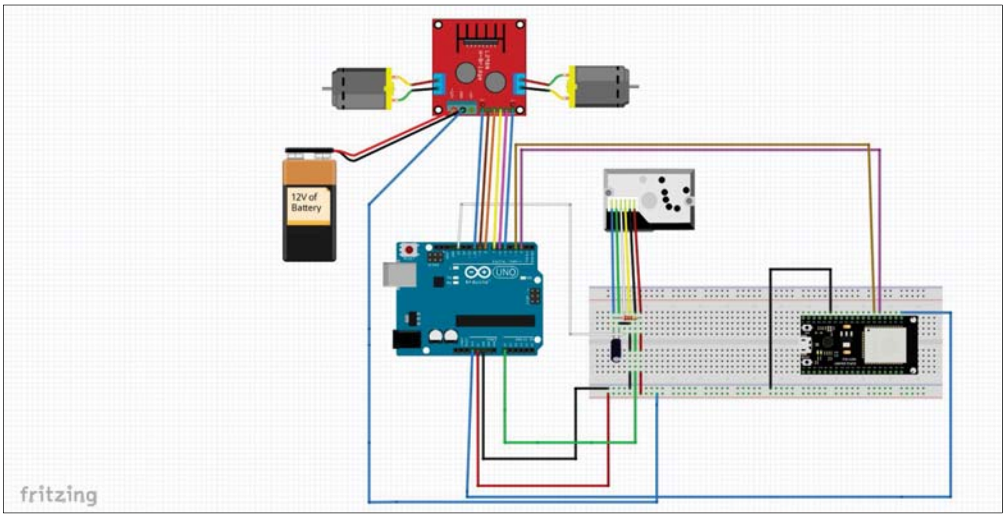


Figure 3.22: Schematic Diagram of IoT-Based Solar Panels Automated Cleaning System

The entire schematic diagram for an automated cleaning system for solar panels is seen above in Figure 3.22, which was created using the Fritzing programme. This schematic diagram demonstrates all of the connections that are made between the various components of the system, such as the dust sensor, motor driver module, dc motor, and ESP32 Wi-Fi module. Both the analogue and digital pins of the Arduino UNO are linked to the dust sensor so that it can detect dust. In addition to that, a connection has been made between the Arduino UNO microcontroller board and an ESP32Wi-Fi module. Utilising Wi-Fi as a method of communication is being done so that an interface may be provided between the sensors that are being developed for the Internet of Things. For instance, the user is able to manage the system and monitor the dust density through the use of mobile applications connected to Wi-Fi as the communication channel.

3.10 Connection between ESP32 Wi-Fi Modules to ThingSpeak

Since the data that was collected has to be communicated to ThingSpeak, it is necessary to connect the Wi-Fi module in order to be able to submit the data. The user will be able to monitor the systems in the channel as well as save data in part due to this functionality. The ESP32 Wi-Fi module requires the programming of a few instructions in order to function properly. The list of commands that need to be programmed into the ESP32 Wi-Fi module are listed in the Table 3.10 below.

Table 3.10: Command for ThingSpeak

Command	Description
#include <WiFi.h>	Includes the WiFi library for ESP32
const char* ssid = "your_wifi_ssid"	Defines the variable ssid with WiFi network name
const char* password = "your_wifi_password"	Defines the variable password with WiFi password
const char* server = "api.thingspeak.com"	Defines the ThingSpeak server address
void setup()	Initialize the serial communication and connect to WiFi
void loop()	Read sensor data, format it and send it to ThingSpeak
float readSensor()	A function to read the sensor data
WiFi.begin(ssid, password);	Connects to the WiFi network using provided ssid and password
while (WiFi.status() != WL_CONNECTED) { ... }	Waits until the ESP32 is connected to WiFi
String data = "field1=" + String(sensorValue);	Formats the sensor value into a string for sending to ThingSpeak
if (httpResponseCode > 0) { ... }	Check if the data was successfully sent to ThingSpeak or if an error occured
delay(5000);	Delays the program for 5 seconds before uploading data again (adjust as needed)

3.11 Connection for Blynk Application on Arduino

The Blynk programme is used since it requires a user interface to function properly. When there is dirt collection on the surface of the solar panels, a system where the user may manually manage the cleaning process is desirable. In addition to that, users of the programme have the ability to monitor the current value of the dust density. There are just a few commands that are implemented on Blynk in order for users to have access to it.

Table 3.11: Command for Blynk

Widget	Virtual Pin	Command	Arduino Code

Button	V1	Pressed: Move motors forward/backward
		Released: Stop motors
			BLYNK_WRITE(V1) {
			 int value = param.asInt();
			 if (value == 1) {
			 moveMotors();
			 } else {
			 stopMotors();
			 }
			}

3.12 Summary

In conclusion, this chapter describes the working principle of automated cleaning system. In addition, block diagram, schematic diagram, connections for each component and software used to connect the system are illustrated and described clearly in this chapter. This chapter also summarizing the functions for each main component used in the automated cleaning.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 IoT-Based Solar Panels Automated Cleaning System

The implementation of the whole complete automated cleaning system of solar panels are available in this chapter. Figure 4.1 show the overall prototype of solar panels automated cleaning system.

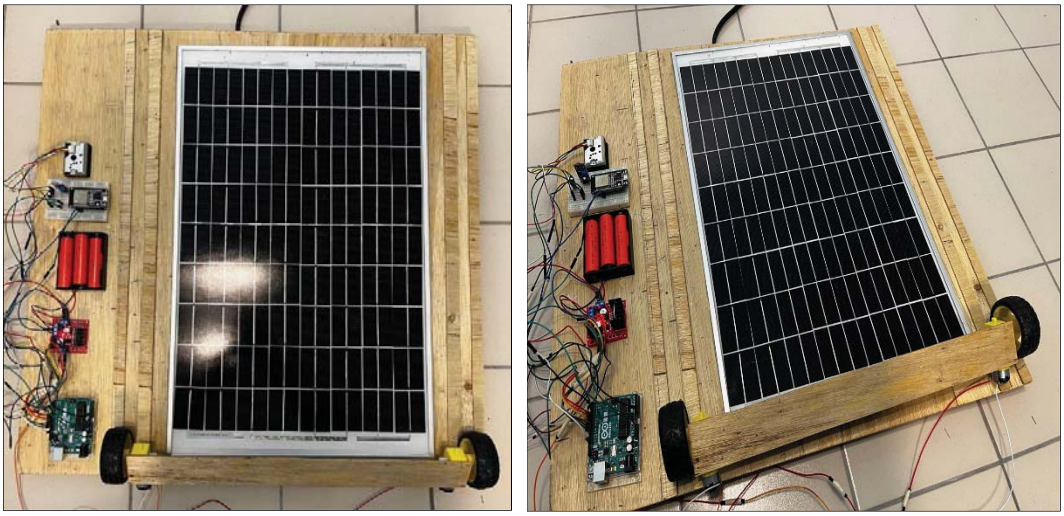


Figure 4.1: Prototype of IoT-Based Solar Panels Automated Cleaning System using Arduino Microcontroller

4.2 Results

The outcomes and contributions of the IoT-Based Solar Panels Automated Cleaning System utilising Arduino Microcontroller project are successfully showcased by providing a results section that is both informative and well-organized. This research presents the effectiveness of an automated cleaning system in preserving the cleanliness of solar panels, including the cleaning cycle, its efficiency, and its impact on the performance of the panels. In addition to this, the results will cover the amount of power consumed, the dependability of communications, and the gathering of data through the

Internet of Things connectivity. A description is given of the user interface as well as the potential of automation. There is a comparison made with the ways of manual cleaning, the limits of the system are discussed, and potential future improvements are offered. These prospective upgrades include hardware advances and software optimisations for improved usability and productivity.

4.2.1 Project Execution

Figure 4.2 illustrates the way the device cleans the solar panel using a pair of DC motors that rotate at a speed of 200 revolutions per minute (rpm). These motors are connected to the wiper mechanism that is responsible for cleaning the solar panel. The system includes a dust sensor that is positioned at the corner of the solar panels in order to detect even the smallest dust particles that may be present on their surface. The dust sensor and motor allow the system to move forward and backward automatically when it is set to the automated mode. The linear equation $y = 170 \times calcVoltage - 0.1$ is used to compute the dust density. In this equation, y represents the dust density and represents a value that is collected from the dust sensor. The results of this computation will assist in establishing the level of particulate matter that is present in the air close to the solar panels.

Figure 4.2: Solar Panels with Dust Accumulation

When the dust density rises over 30 µg/m³, the Arduino will send a signal to the motor module, which will then start the rotation of the DC motor. The purpose of taking this step is to initiate the cleaning procedure in response to the increased levels of dust. The current dust density and air quality are both displayed by the serial monitor system in their respective current states. This information is presented on the serial monitor whenever the dust density is measured to be more than 30 µg/m³, which indicates that the "air quality is bad". On the other hand, the status of "good air quality" is indicated when the dust density is lower than 30 ug/m3, which indicates that the air quality is satisfactory.

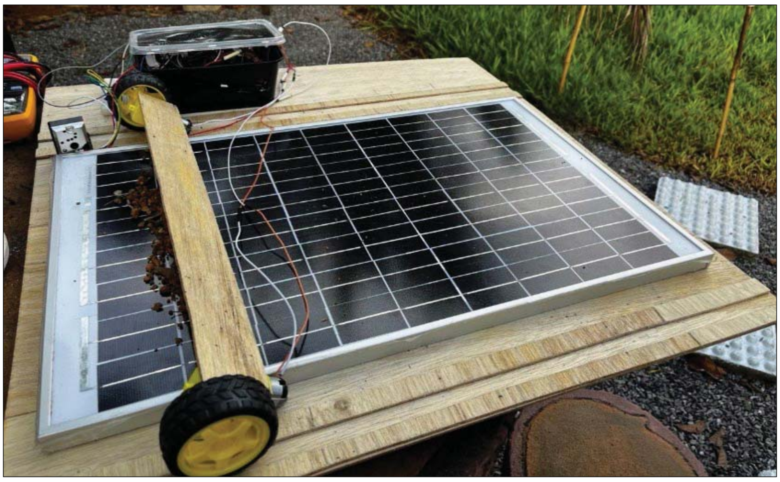


Figure 4.3: Clean Surface of Solar Panels

The motor travels forward and backward down the length of the solar panel for a period of ten seconds, during which it rotates at a speed of two hundred revolutions per minute (rpm). During the cleaning cycle, the motor uses this movement pattern to guarantee that it covers the whole surface of the solar panel. The dust sensor delays 500 milliseconds before determining whether or not there is dust present on the surface of the solar panel. This allows the motor to finish the cleaning cycle without interruption. The dust detection and the motor's cleaning actions are kept in perfect synchronisation attributable to this delay.

The efficient response of the system to any dust that is detected is ensured by the exact synchronisation that exists between the dust detection and the cleaning activities performed by the motor. When the motor detects dust particles on the solar panel, it instantly begins the cleaning process. This efficiently eliminates the contaminants and ensures that the solar panel is able to keep its maximum capacity for absorbing energy from the sun. In contrast, when the dust sensor detects that there is no dust present, the system minimises needless cleaning cycles. This helps to conserve energy and reduces the wear and tear on the components that are responsible for cleaning.

4.2.2 Monitoring Through ThingSpeak

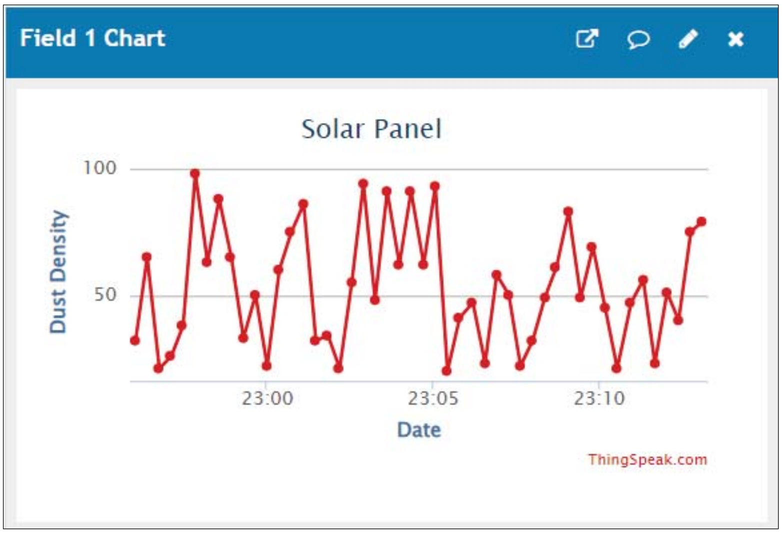


Figure 4.4: Graph of Dust Density in ThingSpeak Website

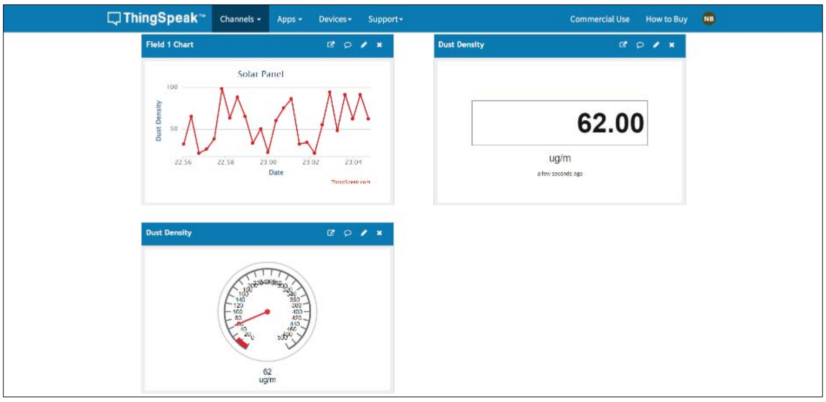


Figure 4.5: Monitoring Screen of Dust Density using ThingSpeak

The output of the dust density is uploaded by the system to ThingSpeak, an internet of things platform that allows for the storage and visualisation of data. This makes it possible to carry out remote monitoring of the dust density levels over a period of time, which provides information regarding the cleanliness of the solar panels. The solar panel cleaning system effectively detects dust levels, begins the cleaning process, and provides real-time monitoring of air quality and dust density since it combines these components and operates in tandem with each other. The integration with ThingSpeak improves data visibility and makes it possible to conduct in-depth analysis and more meticulously schedule preventative maintenance. The user will be able to measure the voltage and current output of solar panels between the dust density over a predetermined amount of time that is included into the system.

4.2.3 Controlling Through Blynk Application

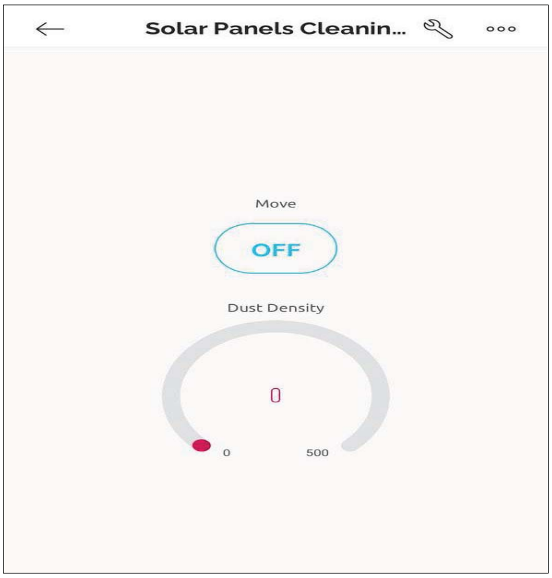


Figure 4.6: Solar Panels Cleaning Control System using Blynk

In the manual mode, the solar panels cleaning system is integrated with Blynk, an IoT platform that facilitates the development of IoT applications. To control the motors, a motor controller is connected to the Arduino. The Blynk app incorporates a button widget assigned to V1. When this button is pressed, the BLYNK_WRITE(V1) function is activated. If the received value is 1, the moveMotors() function is invoked to initiate the cleaning process. Conversely, if the value is 0, the stopMotors() function is called to halt the motor operation. The moveMotors() function is responsible for configuring the appropriate motor control pins to facilitate forward movement for a specified duration. Subsequently, a brief pause is introduced, followed by the setting of pins for backward movement, again for a specified duration. Finally, the motors are stopped by setting all motor control pins to a low state. In summary, the Blynk-integrated code enables the control of the Solar Panels Cleaning System. When triggered by the button widget, the system effectively controls the motors to perform forward and backward movements, facilitating the cleaning process. The stopMotors() function ensures the motors are promptly halted when required.

4.2.4 Output Result

In order to calculate the power output of solar panels, a particular viewpoint must first measure the amount of current and voltage that is produced by the panels. The amount of dust that has accumulated on the solar panels is measured every ten minutes, and the measurement of this output is taken between each of those times. This analysis and observation is carried out on an hourly basis, and then each hour is broken into ten-minute intervals. Both utilising an automatic cleaning system and without utilising an automated cleaning system, the data was collected. The purpose of this is to demonstrate the difference in outcomes gained as well as the efficiency of the cleaning process.

Table 4.1: Solar Panels without Automated Cleaning System

Test Time (Every 10 minutes)	Dust Density (μg/m³)	Voltage Output (V)	Current Output (A)	Power Output (W)
Test 1	44.72	19.06	0.567	10.807
Test 2	45.55	19.03	0.481	9.153
Test 3	48.87	18.89	0.463	8.746
Test 4	57.18	18.63	0.342	6.371
Test 5	63.51	18.59	0.330	6.135
Test 6	65.66	18.28	0.315	5.758
Total Power Output (W)				46.97

The test results of solar panels without an Automated Cleaning System were recorded at 10-minute intervals and presented in Table 4.1. The particulate density on the solar panels increased continuously over the course of the six experiments, from 44.72 μg/m³ in Test 1 to 65.66 μg/m³ in Test 6. This increase in dust density due to the absence of an Automated Cleaning System, the solar panels are susceptible to dust and grime accumulation over time, which could have a negative effect on their efficacy and capacity to generate energy. Throughout the evaluations, the voltage output exhibited minimal fluctuations, ranging from to 19.06 V in Test 1 to 18.28 V in Test 6. In a similar manner, the current discharge ranged from 0.567 A in Test 1 to 0.315 A in Test 6. Even though the variations were relatively minor, they may have been caused by external factors or environmental conditions. The power output, which is the product of voltage and current ($P = V \times I$) varied between 10.807 W in Test 1 and 5.758 W in Test 6. Changes in voltage and current, as well as external factors affecting solar panel performance, could account for the variations in power output. To determine the overall efficacy of energy generation, the total power output of the six experiments was calculated, yielding 46.97 W. This value represents the total amount of energy produced by the solar panels without an Automated Cleaning System over the entire duration of the test, taking into account the effects of dust accumulation on power output. These test results demonstrate the significance of implementing an Automated Cleaning System for solar panels. Without routine cleaning, the particulate density on solar panels will continue to increase, potentially resulting in a decrease in power generation efficiency.

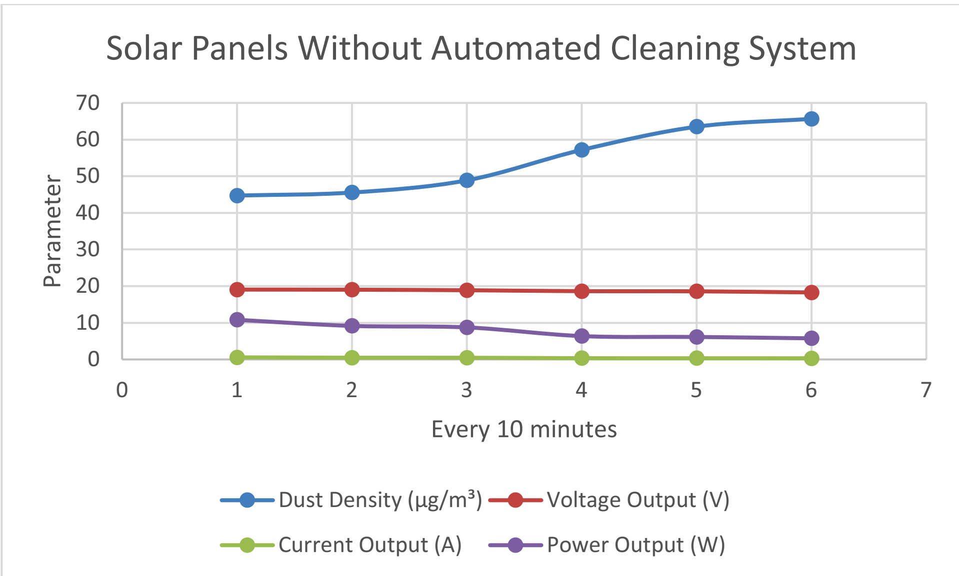


Figure 4.7: Graph Output Solar Panels without Automated Cleaning System

From the graph in Figure 4.7 above, there is a gradual rise in the density of the dust that begins after the first 10 minutes and continues for the next 60 minutes. The readings begin at 44.72 ug/m3 and continue to steadily increase until they reach 65.66 ug/m3. This demonstrates that there is an increase in the amount of dust that is present in the environment over time. Throughout the course of the tests, the values of the voltage output appeared to be inconsistent, ranging from 19.06 V to 18.28 V. This suggests that the voltage output is unstable and is considerably impacted by the variations in the density of the dust. The output as it stands right now demonstrates a downward tendency from 10 minutes to 60 minutes. It falls all the way down to 0.315 A from 0.567 A. This points to the possibility that the presence of dust particles is having an effect on the flow of current through the system, resulting in a decreased amount of current output. During the course of the testing, there is a discernible drop in the figures representing the power output. It drops from 10.807 W in 10 minutes to 5.758 W after 60 minutes. This drop can be due to the combined effects of decreased current output and stable voltage output. Both of these factors have been shown to have a negative impact. There appears to be a connection between the density of the dust and the amount of power that is produced. It has caused a discernible drop in power production that coincides with an increase in the dust density. Given the association between both factors, it is possible to deduce that the presence of dust has a detrimental effect on the performance of the system.

Table 4.2: Solar Panels with Automated Cleaning System

Test Time (Every 10 minutes)	Dust Density (μg/m³)	Voltage Output (V)	Current Output (A)	Power Output (W)
Test 1	45.97	19.57	0.537	10.509
Test 2	42.19	19.69	0.563	11.085
Test 3	36.94	19.93	0.589	11.739
Test 4	32.67	19.96	0.643	12.834
Test 5	31.88	20.15	0.688	13.863
Test 6	30.52	20.37	0.740	15.074
Total Power Output (W)				75.10

In Table 4.2, it is showing the results of tests conducted on solar panels equipped with an Automated Cleaning System, with data collected at 10-minute intervals. The particulate density on the solar panels decreased steadily over the course of the six experiments, from 45.97 μg/m³ in Test 1 to 30.52 μg/m³ in Test 6. This decrease in particle density is attributable to the Automated Cleaning System's effectiveness in eradicating dust and grime from the solar panels. Beginning at 19.57 V in Test 1 and rising to 20.37 V in Test 6, the output voltage gradually increased over the course of the six experiments. In a similar conduct, the current discharge increased throughout the experiments, from 0.537 A in Test 1 to 0.740 A in Test 6. This increase in current output suggests that the Automated Cleaning System kept the surface of the solar panels in good condition, allowing for a greater discharge of electric charge. Throughout the experiments, the power output increased steadily. Beginning at 10.509 W in Test 1, the output wattage increased to 15.074 W in Test 6. By minimising dust-related losses, the Automated Cleaning System effectively preserved the solar panels' efficiency, as evidenced by this significant increase in power production. To evaluate the overall efficacy of energy generation, the total power output of the six experiments was calculated, yielding 75.10 W. This value represents the total amount of energy generated by the solar panels with the Automated Cleaning System over the entire duration of the test, demonstrating the system's ability to maximise power output. These test results demonstrate the significance of using an Automated Cleaning System for solar panels. By consistently sustaining a low particulate density on the surface of the panels, the system has a positive effect on both voltage and current output, resulting in a substantial increase in the efficiency of power generation.

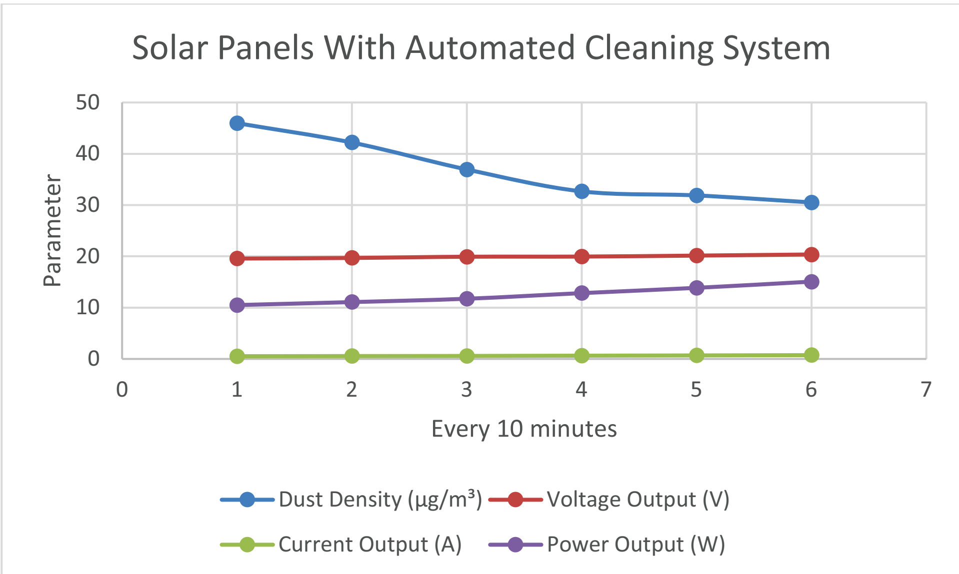


Figure 4.8: Graph Output Solar Panels with Automated Cleaning System

The dust density has been decreasing from the beginning of the first 10 minutes to the end of the first 60 minutes, and the voltage output has shown an overall trend of growing. The output voltage moves up from 19.57 V in 10 minutes to 20.37 V in 60 minutes throughout the course of an hour. This indicates that there may be a potential inverse link between the dust density and the voltage output, which means that a lower dust density may lead to a higher voltage output in this particular circumstance. In a similar vein, an upward tendency may be observed in the current output whenever there is a reduction in the dust density. The current output increases from 0.537 A to 0.740 A from the initial 10 minutes to the final 60 minutes. This shows that there is a possible positive association between dust density and current production; more specifically, it suggests that a lower dust density may result in a higher current output. As the dust density reduces, it is observe that the voltage output as well as the current output both increase, also observe that the power output increases. After an hour has passed, the power production has increased from 10.509 W after 10 minutes to 15.074 W after an hour. This proposes that there is a possible positive association between dust density and power output. More specifically, it conclude that having a lower dust density could result in having a higher power output.

4.2.5 Measurement of Energy Consumption

The energy consumption of the solar panels is calculated once the output power of solar panels is obtained. The equation of measurement for the consumption of energy of solar panels is shown below.

$$Energy\ Consumption\ (kWh) = \frac{Power\ (Watts) \times hours \times 30\ days}{1000} \tag{1}$$

Hence, the energy consumption for solar panels is calculated by using equation (1) given. The parameter of power and hours obtained are substituted in the equation in order to calculate the energy consumption of solar panels with and without automated cleaning system.

<u>Solar Panel without Automated Cleaning System</u>

$$Energy\ Consumption\ (kWh) = \frac{46.97\ Watts\ \times 1\ hour\ \times 30\ days}{1000}$$

$$= 1.41\ kWh$$

<u>Solar Panel with Automated Cleaning System</u>

$$Energy\ Consumption\ (kWh) = \frac{75.10\ Watts\ \times 1\ hour\ \times 30\ days}{1000}$$

$$= 2.25\ kWh$$

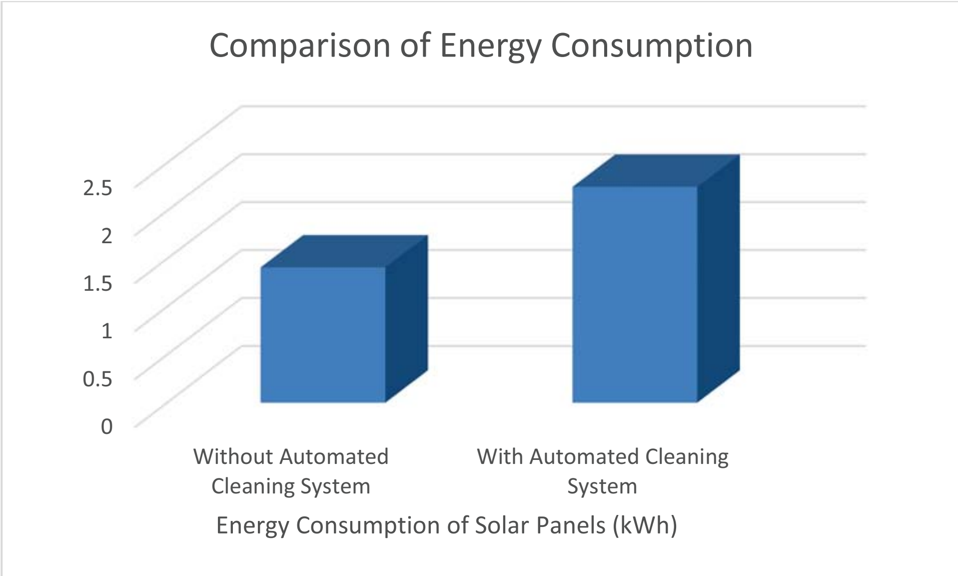


Figure 4.9: Comparison of Energy Consumption Solar Panels

The Figure 4.9 show the graph a depicts the solar panels' energy consumption. The energy production of solar panels without an automated cleaning system is 1.41 kwh, which can decrease more swiftly than the energy production of solar panels with regular cleaning. Using an automated cleaning system, solar panels can be cleansed periodically of dust and debris. This assists in optimising energy production. The energy consumption with an immaculate surface is 2.25 kWh. Consequently, in areas with a high dust density, the automated cleaning system can be especially advantageous because it ensures that the panels remain clean and perform effectively, resulting in greater energy production compared to panels without a cleaning system.

4.2.6 Measurement of Efficiency

Once the energy consumption has been determined, the efficiency of the solar panels can then be computed. The dimensions of the solar panels are taken into account while determining the efficiency of the panels. The specification of the solar panels that were utilised in this project is presented in the equation that can be found below.

Table 4.3: Dimension of Solar Panels[49]

Parameters	Specification
Peak Power (Pmax)	30
Production Tolerance (%)	3

Maximum Power Current (Imp)	1.67
Maximum Power Voltage (Vmp)	18.00
Short Circuit Current (Isc)	1.82
Open Circuit Voltage (Voc)	22.30
Dimension (mm)	$550 \times 340 \times 17$

The equation of measurement for efficiency of solar panel is shown below.

$$Efficiency = \frac{panel\ power\ (in\ kW)}{panel\ length\ \times panel\ width} \times 100 \tag{2}$$

Hence, the efficiency for solar panels is calculated by using equation (2) given. The parameter of panel power, panel length and panel width are substituted in the equation in order to calculate the efficiency of solar panels with and without automated cleaning system.

Solar Panel without Automated Cleaning System

$$Efficiency = \frac{0.04697\ kW}{0.550\ m\ \times 0.340\ m} \times 100\%$$

$$= 25.12\%$$

Solar Panel with Automated Cleaning System

$$Efficiency = \frac{0.0751\ kW}{0.550\ m\ \times 0.340\ m} \times 100\%$$

$$= 40.16\%$$

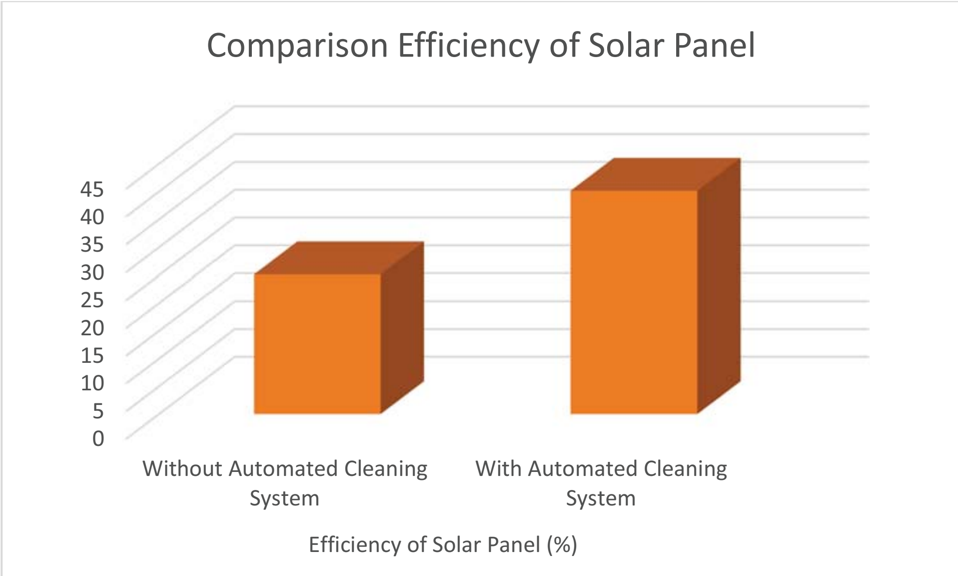


Figure 4.10: Comparison of Efficiency Solar Panels

The comparison of the two graphs makes it abundantly evident that the solar panel that is equipped with an automated cleaning system achieves a substantially greater level of efficiency ,40.16%, in contrast to the solar panel that does not contain such a system, which only reaches 25.12%. This demonstrates that the automated cleaning system plays a significant role in contributing to the improvement of the solar panel's overall performance. It is plain to see that the efficiency of both panels will be impacted as a direct result of the increasing dust density. It brings to light the adverse effects that dust collection has on the efficiency of solar panels. The automated cleaning system guarantees that the solar panel continues to function at a higher efficiency level by periodically removing or minimizing dust accumulation. This results in the maximum amount of energy being generated. The results of this study have important ramifications for the installation of solar panels in areas where there is a lot of dust. The comparison demonstrates that putting in place an automated cleaning system can be a worthwhile investment in some circumstances. Not only does it boost the efficiency right away, but it also helps to keep the performance consistent over time, especially when faced with difficult conditions.

4.3 Summary

This chapter is summarizing the development and implementation of automated cleaning system of solar panels. A prototype, project execution and result output are show in this chapter. IoT-based solar panel automated cleaning system were showing amazing results, cleaning the panels increased production by over 10%, equating to more power. The experiment showed that the solar panel's productivity improved by 15.04%, from 46.97W to 75.10W.

CHAPTER 5

CONCLUSIONS

5.1 General Conclusions

The project provides study regarding the design and implementation of an automated cleaning system for solar panels. In other terms, the purpose of this project is to conserve energy, increase power and enhance efficiency. Utilising sensor technology, the automated solar panel cleansing system was executed. Multiple systems have been developed to demonstrate the sensors' operability. First, dust sensors are installed to detect the accumulation of dust on the solar panels. When the dust sensor reaches a predetermined density, the motor module will be triggered to activate the DC motor. Secondly, the system is capable of autonomously removing dust from the surface of solar panels. Finally, the output data of dust density can be monitored on the ThingSpeak webserver to determine the surface conditions of solar panels. This can prevent grime from accumulating on solar panel surfaces.

In addition to integrating sensors to control the system, mobile applications are an additional feature of this system. Through the Blynk application, the status of the dust density on solar panels can be readily monitored. When there are adhesive surfaces on solar panels that cannot be cleaned, users can manually clean the surface of the solar panels anywhere they choose. With the implementation of an automated cleaning system for solar panels, the efficiency of solar panels can be improved by increasing their energy production.

In conclusion, the implementation of an automated solar panel cleaning system was a success. The primary objective of this study is to develop a low-cost and dependable IoT-Based Solar Panel Automated Cleansing System using Arduino Microcontroller. As a result, all objectives have been accomplished.

5.2 Recommendations

While this study yields valuable insights into the adoption of automated cleaning systems for solar panels, it is important to acknowledge its limitations and suggest areas for future research. Firstly, future studies should focus on incorporating preventative maintenance measures by monitoring parameters such as motor performance, brush wear, and sensor calibration. This will help prevent unexpected downtime and optimize system efficiency. Secondly, there is a need to enhance the dust detection capabilities of the system by implementing advanced image processing algorithms. This will improve the accuracy and sensitivity of dust detection, leading to more effective cleaning operations. Lastly, it is recommended to leverage data analytics techniques to analyse system data, including weather conditions, cleaning cycles, and power production. By identifying patterns and correlations within the data, the system's performance, scheduling, and upgrade decisions can be further improved.

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APPENDIX A

Coding for IoT-Based Solar Panels Automated Cleaning System using Arduino Microcontroller

```
#include <SoftwareSerial.h>
#include <BlynkSimpleSerialBLE.h>
#define BLYNK_TEMPLATE_ID "TMPL6-N6oepdz"
#define BLYNK_TEMPLATE_NAME "Solar Panels Cleaning System"
#define BLYNK_AUTH_TOKEN "J0YtBNaZXRnBSH9hFKQoRz6z5WH2-T25"

// Connect motor controller pins to Arduino digital pins
// Motor One
int enA = 10;
int in1 = 9;
int in2 = 8;
// Motor Two
int enB = 5;
int in3 = 7;
int in4 = 6;

const int ledPin = 13;       // LED pin for indicating dust presence
const int measurePin = A0;   // Analog pin to read the dust sensor output

const unsigned long forwardDuration = 10000;  // Duration for forward motor
movement in milliseconds
const unsigned long backwardDuration = 10000; // Duration for backward motor
movement in milliseconds
```

```
SoftwareSerial espSerial(2, 3);  // RX, TX

char auth[] = "J0YtBNaZXRnBSH9hFKQoRz6z5WH2-T25";

void setup() {
  Serial.begin(9600);
  espSerial.begin(9600);
  pinMode(enA, OUTPUT);
  pinMode(enB, OUTPUT);
  pinMode(in1, OUTPUT);
  pinMode(in2, OUTPUT);
  pinMode(in3, OUTPUT);
  pinMode(in4, OUTPUT);
  pinMode(ledPin, OUTPUT);

  Blynk.begin(espSerial, auth);
}

void loop() {
  Blynk.run();
}

BLYNK_WRITE(V1) { // Blynk app button widget on V1
  int value = param.asInt();
  if (value == 1) {
```

```
    moveMotors();
  } else {
    stopMotors();
  }
}

void moveMotors() {
  digitalWrite(in1, HIGH);
  digitalWrite(in2, LOW);
  digitalWrite(in3, HIGH);
  digitalWrite(in4, LOW);
  analogWrite(enA, 80);
  analogWrite(enB, 80);
  delay(forwardDuration);

  stopMotors();
  delay(1000);

  digitalWrite(in1, LOW);
  digitalWrite(in2, HIGH);
  digitalWrite(in3, LOW);
  digitalWrite(in4, HIGH);
  analogWrite(enA, 80);
  analogWrite(enB, 80);
  delay(backwardDuration);
```

```
  stopMotors();
}

void stopMotors() {
  digitalWrite(in1, LOW);
  digitalWrite(in2, LOW);
  digitalWrite(in3, LOW);
  digitalWrite(in4, LOW);
}
#include <SoftwareSerial.h>
#include <WiFi.h>
#include <ThingSpeak.h>

SoftwareSerial dustSerial(35, 34); // RX, TX

const char* ssid = "vivo 1726";
const char* password = "liyana15";
const unsigned long updateInterval = 5000; // Interval to update ThingSpeak in
milliseconds

const unsigned long channelId = 2199684;    // Replace with your ThingSpeak channel
ID
const char* apiKey = "ZPDLHDIRVQ4U4572";    // Replace with your ThingSpeak
API key

WiFiClient client;
```

```
void setup() {
  Serial.begin(115200);
  dustSerial.begin(9600);

  connectToWiFi();
  ThingSpeak.begin(client);
}

void loop() {
  if (dustSerial.available()) {
    String receivedData = dustSerial.readStringUntil('\n');
    Serial.println(receivedData);
    float dustDensity = receivedData.toFloat();
    sendToThingSpeak(dustDensity);
  }

  delay(updateInterval);
}

void connectToWiFi() {
  Serial.print("Connecting to WiFi...");
  WiFi.begin(ssid, password);

  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
```

```
    Serial.print(".");
  }

  Serial.println("\nConnected to WiFi");
}

void sendToThingSpeak(float dustDensity) {
  ThingSpeak.setField(1, dustDensity);

  int httpCode = ThingSpeak.writeFields(channelId, apiKey);
  if (httpCode == 200) {
    Serial.println("Data sent to ThingSpeak successfully");
  } else {
    Serial.print("Error sending data to ThingSpeak. HTTP code: ");
    Serial.println(httpCode);
  }
}
```

APPENDIX B

<u>Gantt Chart</u>

Semester	1-2022/2023													
Task	Activities by Weeks from the start of the project													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Research on relevant articles														
Study of project background, dust and Arduino software														
Writing of Introduction														
Research and Writing of Literature Review														
Research and Writing of Methodology														
Design of schematic diagram														
Presentation														
Improvement of report and simulation														
Submission														

Semester	2-2022/2023													
Task	Activities by Weeks from the start of the project													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Building the Automated Cleaning System Solar Panels Prototype														
Simulating the Automated Cleaning System of Solar Panels using Arduino IDE														
Writing and preparing for Chapter 4 – Result and Discussion														
Writing and preparing for Chapter 5 – Conclusion														
Writing and preparing for Report														
Preparing Slide for Presentation														
Presentation														
Finalize the Report														
Submission														

APPENDIX C

<u>Hardware Execution</u>

Venue: Electrical and Electronic Workshop, Faculty of Engineering, UNIMAS