IOT-BASED SOLAR PANELS AUTOMATED CLEANING SYSTEM USING ARDUINO MICROCONTROLLER

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Bachelor of Engineering (Hons)

Electrical and Electronics Engineering

2023

UNIVERSITI MALAYSIA SARAWAK

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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
Bachelor of Engineering (Hons)
Electrical and Electronics Engineering

Faculty of Engineering

Universiti Malaysia Sarawak

2023

ACKNOWLEDGEMENT

First, I want to start by expressing my heartfelt gratitude to everyone who has mentored and assisted me in any way throughout the creation of this project. I would like to thank God for blessing me with a healthy body and the motivation to complete this research project independently. I would like to thank most of the people inside and outside of the Faculty of Electrical and Electronics Engineering who helped me with this final year project by giving me advice and giving me a hand. Next, I would like to express my heartfelt gratitude to my research supervisor, Dr. Yonis. M. Yonis Buswig, for allowing me to work on this project titled "IoT-Based Solar Panels Automated Cleaning System using Arduino Microcontroller." I would like to thank him for his guidance, passionate encouragement, and helpful critiques of this research work, as well as for the advice and help he's given me to stay on track.

Furthermore, I would like to thank Dr. Dayang Nur Salmi Dharmiza binti Awang Salleh and Ir Dr Abadi bin Chanik, our FYP coordinator, for leading seminars that explained the project guidelines. In addition, I want to thank me for believing in me, I want to thank me for doing all this hard work. I want to thank me for having no days off. I want to thank me for never quitting. I want to thank me for always being a giver and trying to give more than I receive. I also would like to express my gratitude to my classmates who have been more willing with the helpful ideas and willingness to spend time during the planning and development of this research work were very much appreciated. Lastly, I want to thank my parents, my family, and my friends for their help and support during my studies.

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.

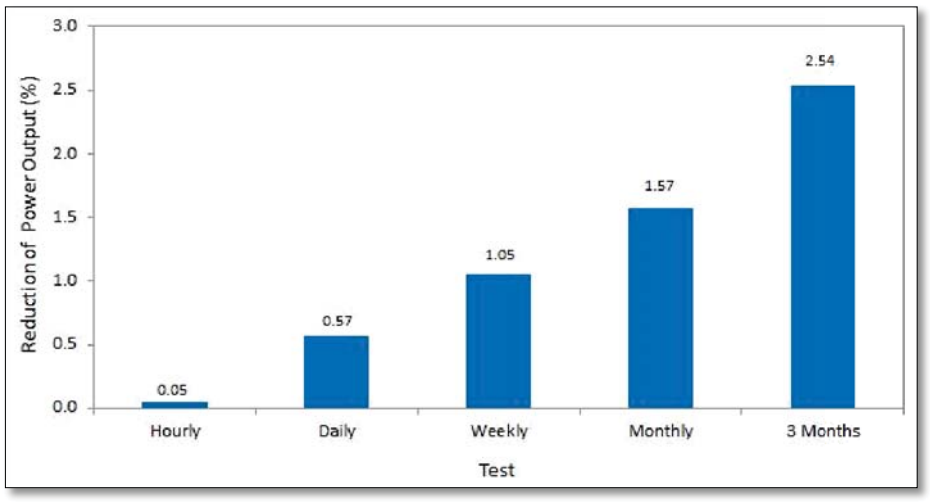

Figure 1.2: Reduction in electrical power output due to dust accumulation for different test durations (Sulaiman et al, 2015)

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