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Robotic Device for Cleaning and Monitoring Photovoltaic Panel Arrays

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Abstract: Technology has improved from time to time including in getting a better performance of a photovoltaics (PV) panels yet less worked needed to maintain the output. However, solar array is usually being placed in an open area, its surfaces are likely to be exposed to impurities that can reduce the solar power generation. Hence, this paper proposed an efficient way to clean a PV array as well as controlling and monitoring the panels via IoT in order to improve the voltage and current output. In the proposed prototype, the output that need to be considered are PV panels surface image, voltage and current output from the PV panels and the efficiency of the robot cleaning to clean more than one panel. The results show that the distance-monitoring model analyses the sensing data and the specific method for measuring the values of adapted sensors and also the self-controlling of the output linked equipment. Since solar has been a high demand market currently, this prototype should be able to operate and fulfill all the market demand.

Keywords: Iot, Distance-Monitoring, Self-Controlling

1. Introduction

Solar energy is considered as one of the most important renewable energy sources within global community. The important of solar photovoltaic panel (PV panels) technology is proved by the fact with the growing demand for renewable energy, which makes solar photovoltaic technology is a topic of major concern nowadays. The efficiency of PV panel's model is determined by the available sun's irradiance along with various environmental factor like humidity, temperature, dust, snow, bird excrement etc. [1][2]. The efficiency of the PV panels decreases with the present of these environmental factors. To optimize PV panels efficiency, it is very necessary to ensure the PV panels remains clean all the time. Cleaning of the solar panels can be both manual and automated. Manual cleaning calls for extensive labor. In addition, perhaps practical manual cleaning to households with a few solar panels. For large-scale projects the situation favors an unmanned automated cleaning system that can

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henceforth take in the data in real time with retrospect to the accumulated dust, generated power and clean. Thus, the idea of using a solar panel cleaning robot came out to make cleaning work easier.

Most of PV panels and solar power plant in remote places as close as a rooftop to a desert as far out. We therefore need sophisticated systems for remote monitoring of such installations by way of wide area networks [3]. Using Internet of Things technology, the power generation can be greatly influenced by means of its performance, monitoring and maintenance [4]. By using apps and mobile, remote cleaning robots can be remotely controlled and solar panel surface conditions and energy output can be monitored online in real time.

1.1 Problem Statement

Nowadays, solar panels are usually set up in open areas exposed to sunlight. Due to the surface of the solar panel is exposed to the open environment, solar panel surfaces are exposed to impurities that can reduce solar power generation. The dust accumulated on the PV module covers and blocks the solar irradiance reaching the panel surface, and this had influenced the current and power output [5]. Therefore, the reduction in solar energy production is a major issue.

In this study, the main focus was to identify on how the cleaning robots are capable of cleaning more than one panel and how the solar panel surface can be monitored in real time. Once the method and technique has been identified, the robot will be developed based on the above-mentioned criteria. This project will ensure that the developed robot able to clean all the solar panels and able to overcome the obstacles such as space between solar panels. In addition, wireless cameras are used to monitor the surface of solar panels.

Furthermore, the material used for cleaning should be confirmed that it will not damage the surface of the solar panel. Therefore, any abrasive material should be avoided for use in developing this solar array cleaning robot.

1.2 Research Objective

The purpose of this study is to developed an efficient cleaning robot for photovoltaic panels in array and to monitor the condition of photovoltaic panels using IoT technology. The measurable objectives for this project are as followed:

1. To design and produce efficient robot cleaning system for PV panel arrays;
2. To develop a faster and reliable robot cleaning mechanism;
3. To develop a fully functioning camera monitoring.

1.3 Research Scope

The scope of the study is to produce and improve the solar panels robot cleaning system using Arduino UNO and have the ability to monitor the surface condition and output parameters of the solar panels. Therefore, the project scopes are:

- Use Arduino UNO as the main system.
- Using DC motor as the movement of cleaning robot.
- A robot cleaning system which can clean more than one PV panels.
- Using IoT approach to monitor the condition of the PV panels.

2. Literature Review

2.1 Operational Efficiency

If the temperature rises for the cells, the performance of photovoltaic panels is declining, resulting in electricity deduction [6]. Operational efficiency can be described as the ratio between a product design output and the product operations. Instead from using one robot to clean one panel, this project is mainly focused on develop one robot to clean an array of solar panel. It is suggested that a robot cleaning mechanism is able to clean several solar panels in arrays efficiently and effectively.

2.2 Method for cleaning system

Previous study shows that a robotic cleaner managed to clean a panel and increase the output efficiency of the solar panel. However, each solar panel needed a robotic cleaner to clean the surface. This will lead to larger cost consuming especially when one has larger amount of solar panel. In this project, the concept of cleaning is still the same but the main purpose was to develop a much more efficient design that can save a lot of cost for consumer.

2.3 types of cleaning robot for solar panels

2.3.1 Microcontroller based SPCR system cleaning robot [7].

Authors: Omur Akyazi, Erdinc Sahin, Timur Ozsoy, Mehmet Algul
Published: First received 1 August 2019 and in final form 25 October 2019

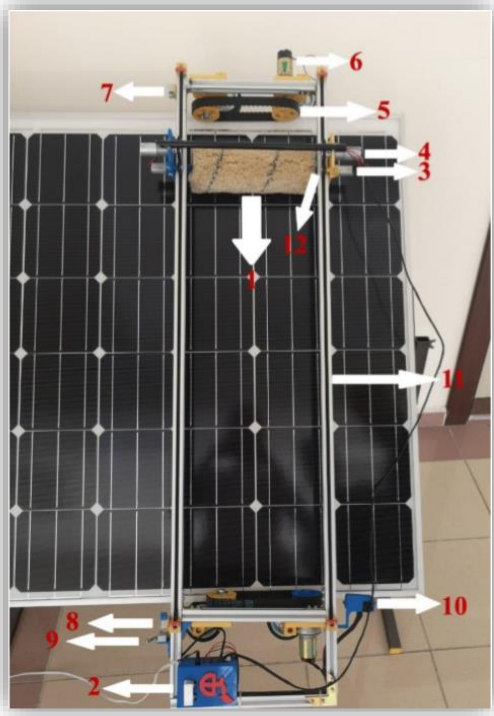

Figure 1: Microcontroller based SPCR system cleaning robot

In this paper, authors have made a robot that during the standby time, the machine stores electricity. When triggered, the cleaning brush starts spinning and going down the PV panel vertically. When a PV panel is swept, the brush ceases rotating, and it grows vertically, transferring SPCR to the other PV panel horizontally. This loop continues until the PV list stops. The unit then goes back to the car park and starts paying. While the waiting of the activation order in the parking station on the left side of the PV collection, it is paid. The first phase in the loop process is vertical flow. With the assistance of DC motors the brush travels about. The SPCR shifts to the right side in the next cleaning region and often pushes the brush upwards towards the top of the device until the cleaning phase is through. The loops run to the end of the tables. When the process is done, it goes back to the standby platform.

2.3.2 PVCleaner Robot V1.0 [8]

Authors: Mark Anderson, Ashton Grandy, Jeremy Hastie, Andrew Sweezey, Richard Ranky, Constantinos Mavroidis. Yiannis P. Markopoulosy
Published: September 2009

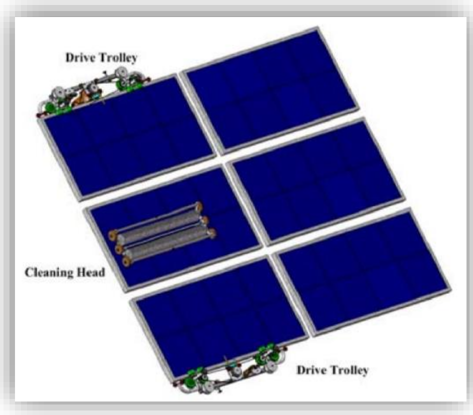

Figure 2: PVCleaner Robot V1.0

The PVCleaner Robot V1.0 consists of a cleaning head going over the panels with a pair of motorized carriers that run along the top and bottom of the arm. Thanks to its modularity, flexibility and extensibility, this style was chosen. The cleaning head will quickly be shifted about on the wall, at the lowest chance of rubbing the panels with the remainder of the window moving mechanism instead of the mirror. The expandability of this nature allows constant flexibility across a range of sizes. Since not all panels or screens are of the same dimension, this device can easily be adjusted to the amount of panel lines by interchanging belts. The columns of the panels are continuous because the robot can cross side borders between the frames of the panels.

3. Methodology

3.1 Flow of controlling system

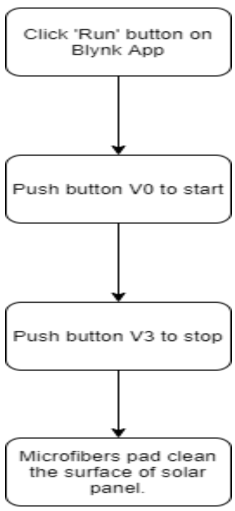

Figure 3: Flow diagram of controlling system

The controlling part for the robot cleaner is show as in Figure 3. After assemble all components, open Blynk app and run the program. Make sure ESP8266 is connected to the network too. There are two buttons used for motor control; V0(forward) and V3(reverse). Microfiber mop is attached below the robot surface does when the robot moved the mop will clean the panels surface.

3.2 Method for monitoring

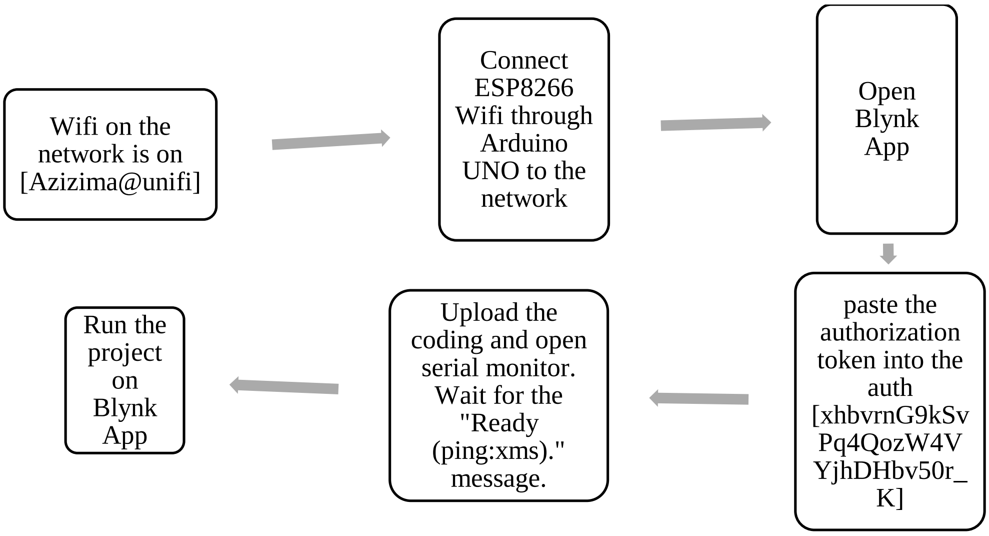

Figure 4: Flow of Blynk Connection

Figure 4 shows the process to connect Blynk app with Arduino. Using Arduino IDE as the coding software and ESP8266 as the connector between Arduino UNO and Blynk. First, setup the network name and password (if available). Then, download Blynk from playstore and create a new account or program. Copy the auth token received from the email register. Lastly, upload the coding into Arduino and the project is save to run.

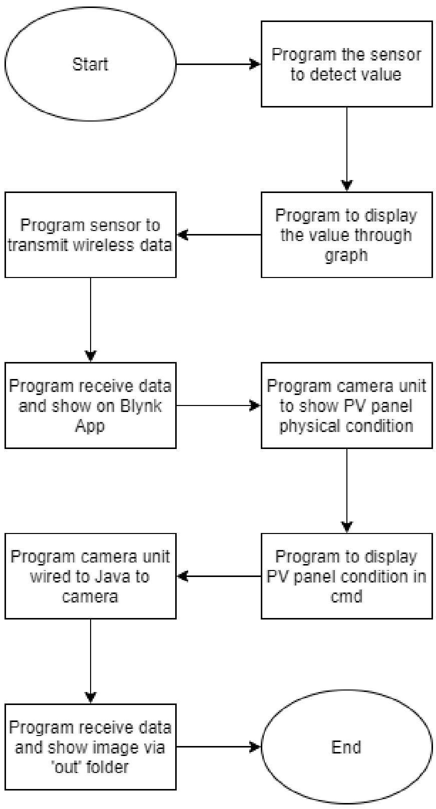

Figure 5: Monitoring Design Flowchart

Figure 5 shows coding process of the monitoring. There are three types of monitoring, which is voltage and current output and PV panels condition via Cmd. As for the voltage and current output, voltage and current sensor will detect the value respectively and the value will be displayed at Arduino serial monitor or Blynk app. Meanwhile the camera will capture live condition of PV panels and the program will receive the data and display the image via “out” folder.

3.3 Block Diagram of the System

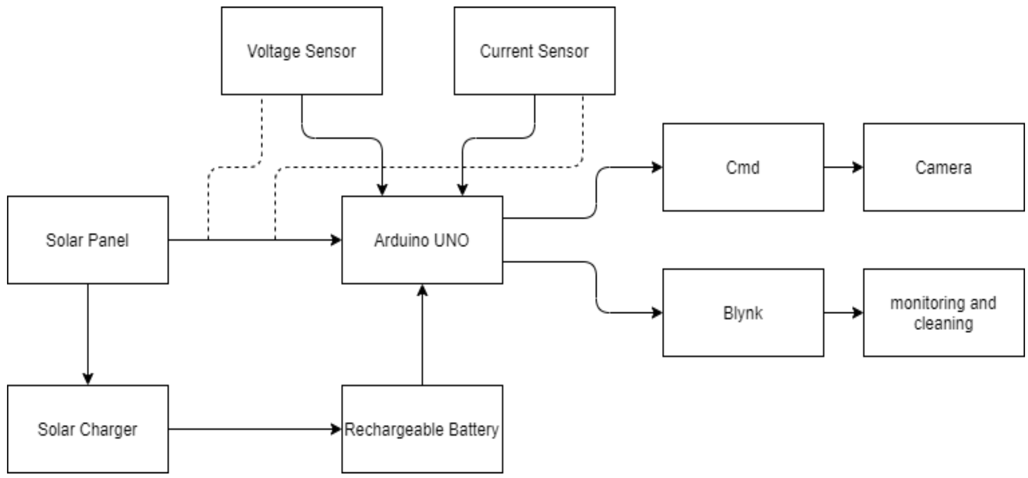

Figure 6: Block Diagram of robotic device for cleaning and monitoring photovoltaic panel arrays

Cleaning and control device are illustrated in Figure 6. There are several main components for the input and output of the system. The device is configured for rechargeable batteries, remote control (Phone), voltage and current sensors, and solar panels as a key source of power. The cleaning system will be control remotely and the monitoring system can be done by observing the condition through camera and the output value of solar panel will display in Blynk App.

3.4 Monitoring the output value of the solar panel

In this project, some calculation is taken to measure and compare the output value of the solar panel before and after cleaning process. This approach is often used to diagnose errors from measurement-calculation observation.

3.4.1 Voltage, Current, Power and Efficiency

$$Vout = IR \qquad Eq.1$$

By using the specified valued the formula will explicitly measure the voltage production. In series relation, the formula can be used.

$$Vout = \left[\frac{R2}{R1+R2}\right] * Vin \quad Eq.2$$

The voltage generated using a voltage divider can be determined by this method. This can be used for parallel circuit calculation.

$$Iout = Iin \qquad Eq.3$$

Theoretically, in series circuit, the current value is equal between input and output.

$$Iout = \frac{Vin}{R} \qquad Eq.4$$

The current is proportional to voltage through resistors, while in the parallel circuit.

$$Pout = Vout * Iout \qquad Eq.5$$

Power output can be calculated by multiplying the voltage output and current output value.

$$n = \frac{Pout}{Pin} \qquad Eq.6$$

Power efficiency is defined as the power output ratio divided by the power supply.

3.5 Components

3.5.1 Arduino UNO

Figure 7: Arduino UNO

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button. Simply connect it with a USB cable computer or power it to start up with an AC-to - DC adapter or battery [8].

3.5.2 Solar Photovoltaic Panel

Figure 8: Polycrystalline solar panel

Polycrystalline solar panels compose of related items. Therefore, the silicon element is used instead of quick and expensive output in a specific cycle molten silicone crystal is set in cast and refroided crystal with a base. Solar panels are built to produce electricity and can be used to supply or recharge power equipment.

3.5.3 Microfiber Cloth

Figure 9: Microfiber mop pad

Microfiber is an extra-thin, much slimmer lightweight fiber than a silk line. Cleaner items, particularly cloths and mops, are the most popular uses for microfibers.

3.5.4 Rechargeable Battery

Figure 10: Lead acid rechargeable battery

This kind of battery, which uses sponge lead and lead peroxide, is called lead acid battery in the system for the conversion of chemical resources into electric fuel. Because it has hi-cell voltage and lower costs, lead acid battery is most commonly used in power stations and substations

3.5.5 Sensor

Sensors are simply a system capable of sensing or recognizing and reacting to such electrical or optical signals. There are several types of sensor use in the project.

3.5.5.1 Voltage Sensor

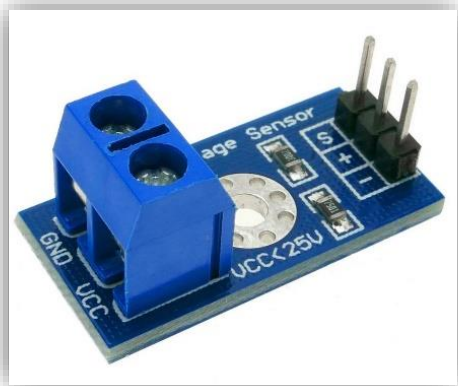

Figure 11: Voltage sensor

For measuring and tracking the voltage of an entity, a voltage sensor is used. AC- or DC-voltage level may be calculated by the voltage sensors. The voltage can be the input of this sensor and the output is analog voltage, analog signals, current, audible signal etc.

3.5.5.2 Current Sensor

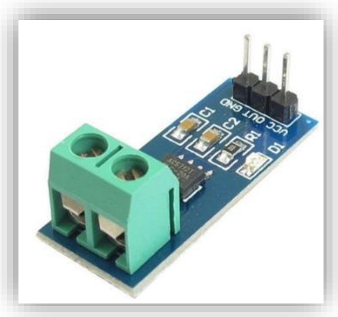

Figure 12: Current sensor

The current indicator is used for measurement of electric current in a wire which produces an appropriate signal. Analog voltage, current or even digital output may be the signal produced.

3.5.6 ESP8266 Wi-fi Shield

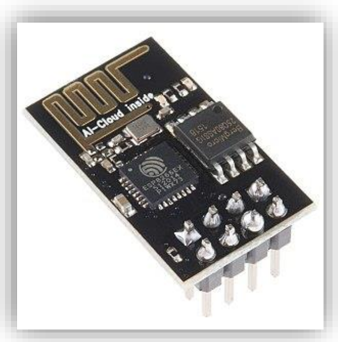

Figure 13: ESP8266 Wi-fi Shield

It is plug and use for Arduino users with this ESP WiFi protection. The shield is pre-assembled with WROOM-02, which gives Wi-Fi connectivity to your Arduino board or device.

3.5.7 L298N motor driver module

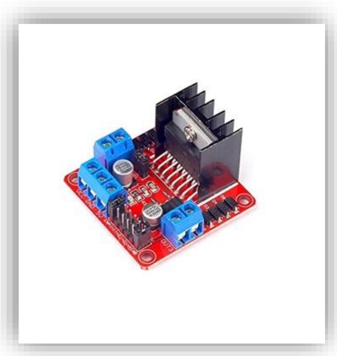

Figure 14: L298N Motor Driver Module

The L298N engine driver software is a platform for high-power DC and Stepper moving motors. This package is made up of an IC processor L298 and a 5 V control panel 78M05. L298N Module with directional and speed control will power up to 4 DC motors or 2 DC motors. This dual H-bridge driver manage to driving voltages up to 46 V and continuous up to 2 A in each channel.

Figure 15: OVA7670 Camera module without FIFO-VGA-30fps

The camera module was used to monitor the PV panels surface condition and the data will be send via online.

3.6 Software Development

There are three software use for simulation and programming such as;

1. Arduino IDE
2. Proteus
3. Fritzing

3.6.1 Arduino IDE

For C and C++ modules, Arduino IDE may be written. It is used to write and upload programs to compatible Arduino boards and other product creation boxes with the aid of third-party cores. All the process that has been program will be uploaded to Arduino board for execution [9].

3.6.2 Proteus 8.1

Proteus 8.1 is a program resource set that is used mainly for development of computer projects. The key aim of the program is to generate schematics and electronic prints for the development of printed circuit boards by electronic engineers and technicians [10].

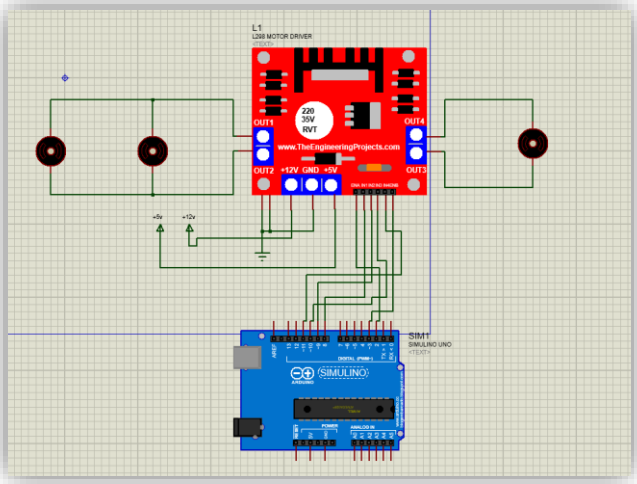

Figure 16: Proteus 8.1 Software

3.6.3 Fritzing

Fritzing is a resource available to everyone for training, exchanging and designing their online creations. It helps users to formulate a diagram and thereby to add a component to rather qualified cable diagrams. The consumer can also build and create his own PCBs from the files they build.

4. Result and Discussion

The robot managed to move and clean the solar panel as expected and the controlling work manually via Blynk app.

4.1 Monitoring and Controlling

Figure 17: Solar panel with Cleaning Robot

Figure 16 shows the completed design of PV panels. Both panels are connected to each other. The controlling and monitoring of the cleaning robot is via Blynk app. There are two types of button for forward move and reverse move of the cleaning robot. As well as current and voltage reading are shown inside the Blynk app too.

Figure 18: Controlling and Monitoring display on Blynk

The prototype was tested for three days between 3rd January 2021 to 6th January 2021. After the testing, data recorded inside the laptop from PV panels is lost due to laptop failure. The output value of the voltage and current has been recorded in the other day in one day only. Table 1.1 shows the written data recorded of rechargeable lead acid battery.

Table 1: Monitoring output value of the Battery

Test condition	Voltage value
Before charging	1.2 V
After charging	12.6 V

The approximate voltage for a regular lead acid battery is 2 V/cell, so a complete battery voltage is 12 V (6 cells in general) [11]. The maximum voltage value that the battery can charge is 14.0-14.4 V. However, due to some losses the voltage has drop 1.8 V from the maximum charged value. This is due to the output of solar panel that charging the battery has been reduced to the cloudy weather.

Table 2 :Monitoring output of Solar panel

Solar condition	Voltage value
Clear	17.5 V
With flour	15.1 V
After cleaning	17.3 V

The PV panel has been tested to see how much different the output voltage value based on the solar condition. Table 2 shows the resulted recorded in one day. The voltage does drop significantly when the PV panels has disturbance cover the surface [12]. After the cleaning process, the voltage returned to original value.

The camera use in monitoring cannot be implemented into the project due to component failure due to sparks occurs and damaging the parts. However, spare part for camera are expected to be arrived soon from China and was still in the development.

5. Conclusion

The prototype of the cleaning and monitoring robot for solar photovoltaic has not been successfully developed and achieved. The prototype is uncapable to captured any image to display the surface of PV arrays. The Cmd experiencing an internal failure which is burned out. However, the controlling part of the robot cleaner work well and successfully achieved.

Acknowledgement

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References

[1] N. Khadka, B. Adhikari, A. Bista, and A. Shrestha, “Solar Panel Cleaner Technology : A Review Solar Panel Cleaner Technology : A Review,” *Researchgate*, no. April, 2018.

[2] N. Khadka, A. Bista, B. Adhikari, A. Shrestha, and D. Bista, "Smart solar photovoltaic panel cleaning system," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 463, no. 1, 2020, doi: 10.1088/1755-1315/463/1/012121.

[3] A. Kekre and S. K. Gawre, "Solar photovoltaic remote monitoring system using IOT," *Int. Conf. Recent Innov. Signal Process. Embed. Syst. RISE 2017*, vol. 2018-Janua, no. October 2017, pp. 619–623, 2018, doi: 10.1109/RISE.2017.8378227.

[4] M. Suresh1' et al., "Fault Detection and Monitoring of Solar PV Panels using Internet of Things," Int. J. Ind. Eng., vol. 2, no. 6, pp. 146–149, 2018, [Online]. Available: http://ijie.gjpublications.com.

[5] R. J. Mustafa, M. R. Gomaa, M. Al-Dhaifallah, and H. Rezk, "Environmental impacts on the performance of solar photovoltaic systems," *Sustain.*, vol. 12, no. 2, pp. 1–18, 2020, doi: 10.3390/su12020608.

[6] O. D. H. Abdulrazig, "AND (P HOENICS) SOFTWARE," no. September 2016, 2019.

[7] Ö. Akyazı, E. Şahin, T. Özsoy, and M. Algül, "A Solar Panel Cleaning Robot Design and Application," *Eur. J. Sci. Technol.*, no. February, pp. 343–348, 2019, doi: 10.31590/ejosat.638291.

[8] E. Yuan and E. Yuan, "H ow t o d eve l o p go o d gero n tec h n o logy product s and ser vices," vol. 13, no. 2, pp. 134–138, 2014, doi: 10.1142/9789814291279.

[9] Singh, Rajesh & Gehlot, Anita & Singh, Bhupendra. (2019). Introduction to Arduino and Arduino IDE and toolbox_arduino_v3. 10.2174/9789811410925119010002.

[10] R. E. Echendu and H. N. Amadi, "Design and Implementation of an Off-Grid Solar Tracker Control System using Proteus Version 8 . 1 International organization of Scientific Research," vol. 08, no. 4, pp. 4–12, 2018.

[11] C. M. Diniş, G. N. Popa, and A. Iagər, "Study on sources of charging lead acid batteries," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 85, no. 1, 2015, doi: 10.1088/1757-899X/85/1/012011.

[12] A. Al-tarawneh, M. Z. Ahmed, and A. Al-tarawneh, "The Effect of Soiling and Periodic Cleaning on the Performance of Solar Power Plants in Ma ' an , Jordan," *Innov. Syst. Des. Eng.*, vol. 9, no. 1, pp. 14–18, 2018.