An Automated Solar Panels Monitoring and Cleaning System: A Case Study of Kaduna Polytechnic, Nigeria

Ahmad Muhammad Bello[1], Deepak Kumar Joshi[2], Muhammed Rufai[3] and Umar Faruq Ibrahim[4]

[1,3,4]*Department of Electrical Electronics Engineering, Kaduna Polytechnic, Nigeria.*
[2]*SAssistant Professor, Department of Electrical Engineering, Mewar University, India.*

[1]bamuhammad@kadunapolytechnic.edu.ng
[2]hodee@mewaruniversity.co.in
[3]mrufai@kadunapolytechnic.edu.ng
[4]umarfarouk@kadunapolytechnic.edu.ng

***Abstract*— The use of Photo Voltaic (PV) panels for the generation of electricity has received a lot of attention from both industries and academia as a renewable energy source due to inadequate electricity from the grid, its low cost as well as environmental benefits. However, the efficiency of solar panels can be significantly affected by major issues such as the accumulation of dust or dirt particles on their surfaces. Therefore, this study presents the design and construction of an automatic based PV monitoring and cleaning system. The system comprises electromechanical parts such as microcontroller, servo motor, submersible pump, voltage sensor, Light Dependent Resistor (LDR) sensor and metal frame. In addition, a modified Blynk application was integrated with the system to remotely monitor and control the performance of the panels. Several tests were carried out by using 150Watts panel installed in the Department of Electrical Engineering, Kaduna Polytechnic. The experimental results obtained shows that the output power of the panel decreases as the dust or dirt particles increases. However, the performance of the panel improved when the cleaning process was carried using the proposed methodology in terms of output voltage, current, and power levels with a value of 13.76%, 17.46%, and 33.61% respectively.**

***Keywords*— Blynk application, Light Dependent Resistor (LDR) sensor, Microcontroller, Photo Voltaic (PV) panels.**

I. Introduction

For the past decades, one of the major problem facing Nigeria as a nation is inadequate supply of electricity from the Grid, resulting to shut-down of many industries such as Kaduna's textile

among others. Hence, negatively affecting the economy of the nation and also increases the rate of unemployment. To address this, solar system was introduced.

Presently, solar energy accounts for about 4.5% of the total electricity production capacity worldwide [1]. However, despite all these advantages, the performance of solar panels can be significantly affected by particles such as dust and moistures. The presence of these particles on solar panels reduces the amount of sunlight reaching the photovoltaic cells, resulting in a decrease in electricity production. To determine the effect of dust on solar panels, several studies have revealed alarming results. According to these studies, the efficiency of solar panels can decrease by 30% to 40% due to dust accumulation, leading to a reduction in power output of up to 86% [2]. These figures highlight the critical importance of regular cleaning of solar panels to maintain their optimal performance. Therefore, solar power plant needs to be cleaned at least every 3 days. Hence, a PV cleaning system is required to maintain as well as prevent the solar panels from deficiency of converting the solar energy into electricity due to the presence of dust particles or moistures on its surface, and as such improving the performance of the entire solar system.

In this study, an automatic based PV monitoring and cleaning system is presented. The system comprises electromechanical parts such as microcontroller, servo motor, submersible pump, voltage sensor, Light Dependent Resistor (LDR) sensor and metal frame. In addition, an IoT based platform was incorporated with the system to remotely monitor and control the performance of the panels. The IoT ecosystem comprises web based smart application that utilize embedded system like processor, sensor and communication hardware, to gather, transmit and act on data it obtain from its surroundings. IoT platforms share the sensor data it gather via connecting to an IoT pathway or other edge devices where data is either sent to the cloud to be evaluated or studied locally [3].

The rest of the paper is organized as follows: Section 2 presents review of related works, materials and method is presented in section 3, section 4 presents the experimental results, while conclusions are done in section 5.

II. Related Works

This section presents the review of related works that have been carried out in the area of PV cleaning system. There exist two major methods for PV cleaning namely; manual and automatic cleaning methods. The manual cleaning approach involves human operator to manually clean the panels using mop or any form of wiper with suitable support structures. While, the automatic cleaning approach involves the use of technology to remove any dust particles without human involvement. In this regard, an automatic cleaning system using mechanical cleaning mechanism was designed and implemented [4]. The system consists of one bracket which is mounted on side of solar panel array having rack and pinion system. It converts rotational motion into translational motion with required torque. The roller mechanism has one roller mounted just above the surface of panel which rotates with particular speed in linear direction. Spray motor incorporated with roller brush made by soft material was also used in the system to supply water as well as cleaning. In addition, gear wheels (Rack and pinion) were used for upward and downward movement of system. It was observed that the system cleans the dust particles present on the panel in downward direction. However the system cannot be controlled remotely.

A conceptual system to monitor the state of a photovoltaic system through an IoT based network was presented [5]. Through the mobile radio network, the information from the sensors was transmitted. To send data to the remote server, a GPRS module was employed. Furthermore, a sophisticated web-based application was designed based on the data collected, processed and stored, to enable the user to monitor the performance of the plant. Another system based on automatic Solar Panel Cleaning was designed and implemented using brush driven by DC motors [6]. The action of the brushes was controlled by signal generated by Arduino microcontroller, the frame carrying this cleaning brush was moved along the length of the solar panel in vertical direction of 11ft and vice-versa, which results in mopping action on the solar panel cleaning the panels.

III. Methodology

The overall methodology can be summarized in the block diagram presented in Figure 1. An explanation of each block is presented herewith.

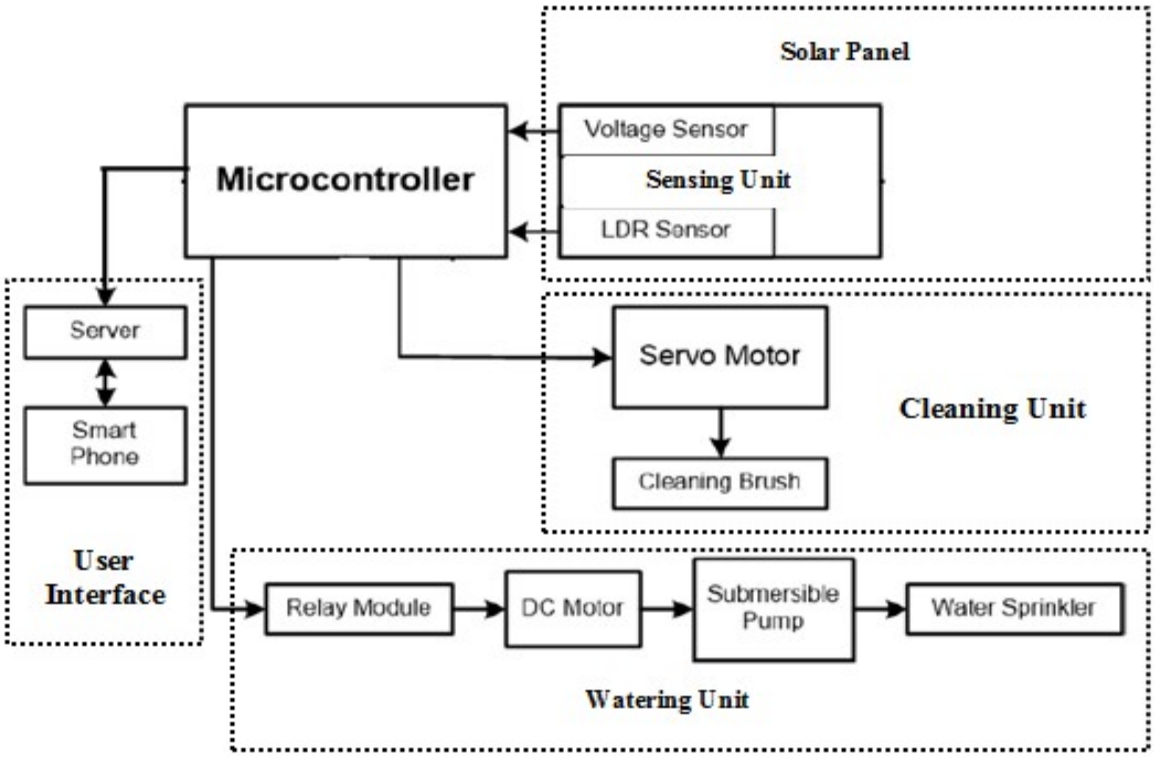

Figure I. Block Diagram of the Proposed System

Figure I present the block diagram of the proposed system. The system comprises five (5) main units, namely; sensing unit, cleaning unit, watering unit, user interface unit, and microcontroller unit.

A. Sensing Unit

This unit comprises two (2) sensors, namely; the voltage and LDR sensors. These sensors are embedded on the solar panels.

The voltage sensor was used to determine the voltage level of the solar panel and the LDR sensor to detect the rate of sunlight dropping on its surface. If dust particles are present, then the surface is less exposed to light and hence the LDR resistance increases. If the thickness of dust is higher, then the LDR resistance is higher due to the resistance of the light passing through it as a result of the dust particles. The LDR sensor then provides a signal to the microcontroller regarding the intensity level of the sunlight. So, if the output voltage from the panels is less than the predefined threshold value, then the microcontroller will determine whether the solar panel is dirty or not by comparing the detected voltage levels of these two sensors.

B. Cleaning Unit

This unit comprises DC servo motor and soft brush. The DC servo motor was used to position and move the cleaning brush which was connected to the output shaft of the motor in order to clean the solar panel surface completely and effectively. The DC servo motor was chosen due to its low operating voltage 4.8V.

C. Watering Unit

In this unit, a relay module, dc motor, submersible pump, and water sprinkler were used. The submersible pump was connected to the water reservoir to spray water on the solar panel when it gets dirty. The submersible pump is driven by a DC motor, which is activated by the relay module. The relay module gets the excitation signal from the microcontroller based on the cleaning requirement.

D. Control Unit

An ESP32 microcontroller was employed to serve as the central controller of the entire system. The microcontroller was used to integrate the different components connected through the sensors in order to have a robust network. In addition, the microcontroller can detect if there's dust particles on the panels or not by comparing the sensed voltage levels of these two sensors. So, if the output voltage level sensed from the sensing unit is below the predefined threshold value, then the microcontroller activates the watering and cleaning units.

E. User Interface

In this unit, an IoT platform using a Blynk application was designed and connected to the cloud server to ensure that the user can monitor as well as control the system's performance remotely and make necessary adjustments. In addition, it helps in gathering data from the panels, monitoring the voltage generated, and automating the cleaning process.

IV. Results and Discussion

This section present the results obtained after the successful realization of the proposed system. Various tests were conducted, and the performance of the system was validated and compared with the standard rating of the panels based on output voltage and current, as well as output power. These tests and measurements were carried out under peak sun hours of Kaduna state,

Nigeria (10:30 – 14:30 GMT+1) using Multi meter. The results obtained are summarized in Table I.

Table I. Results Obtained

Performance Metrics	**Standard Panel Rating**	**Dusty Panel Rating**	**Cleaned Panel Rating Using the Proposed System**
Voltage (V)	20.10 V	17.23 V	19.60 V
Average Current (I)	8.80 A	6.13 A	7.20 A
Power (P_{out})	176.88 Watts	105.62 Watts	141.12

Table I presents the results obtained after subjecting the panel to dust particles and the cleaning process using the proposed system. It can be seen that the voltage and current levels decreases to 17.23V and 6.13A under the effect of dust particles compared to the standard value of 20.10V and 8.80A of the panel respectively. Hence, results to decrease in the output power to 105.62Watts respectively.

It can also be observed that the voltage and current levels of the panel increases to 19.60V and 7.20A after undergoing the cleaning process using the proposed system. Hence, results to increase in the output power to 141.12Watts.

Therefore, it can be concluded that the proposed system has improved the performance of the panel in terms of the output voltage, current, and power levels with a value of 13.76%, 17.46%, and 33.61% respectively when compared with that of the dusty panel.

V. Conclusion

In this study, the authors presented the design and construction of an automatic based PV monitoring and cleaning system to improve the performance of solar panels. The system is incorporated with a modified Blynk application to remotely monitor and control the performance of this panel. Several tests were conducted under the peak sun hours (10:30 – 14:30 GMT+1) of Kaduna state, Nigeria. The performance of the panel after undergoing cleaning process using the proposed method was compared with that of the dusty panel. The experimental results obtained shows that the proposed methodology improves the performance of the panel in terms of all the evaluation metrics.

References

[1] Azarpour, A., Mohammadzadeh, O., Rezaei, N., and Zendehboudi, S. 2022. Current status and future prospects of renewable and sustainable energy in North America: Progress and challenges. Energy Conversion and Management, 269, 115945.

[2] Gochhait, S., Asodiya, R., Hasarmani, T., Patin, V., and Maslova, O. 2022. Application of IoT: A Study on Automated Solar Panel Cleaning System. In 2022 4th International Conference on Electrical, Control and Instrumentation Engineering (ICECIE) (pp. 1-4). IEEE.

[3] Yahya, M. S., Muhammad, B., Abubakar, M. A., Abdullahi, U. I., and Musa, Z. I. (2023). Implementation of a Real-Time IoT Based Energy Management System. Journal of Engineering Research and Reports, 25(10), 19-29.

[4] Manju, B., Bari, A. and Pavan, C.M. 2018. Automatic solar panel cleaning system. International Journal of Advances in Scientific Research and Engineering (ijasre), 4(7).

[5] Venkatarao, K.N. and Kumar, K.V., 2017. An IoT based smart solar photovoltaic remote monitoring. International Journal and Magzine of engineering technology, management and research.

[6] Gode, C., Gajbhiye, A., Meshram, B., Khobragade, A., Desai, S., and Thote, D. 2023. IoT based Solar Panel Cleaner: A Computer Control System. In 2023 International Conference on Communication, Security and Artificial Intelligence (ICCSAI) (pp. 754-757). IEEE.