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doi:10.15199/48.2023.04.28

IoT-based remote cleaning tool for solar system

***Abstract**. Solar power is one of the important clean and renewable energy sources and it is essential for meeting future energy demands. Despite this, the accumulation of tiny dust, bird droppings, and other airborne debris will hinder sunlight from reaching the solar cell's surface. This is a significant problem since the materials that block light act as an external impedance and reduce the performance of solar-powered photovoltaic systems. When the dust has been formed on the panels, its efficiency will reduce by more than 60%. In a sequel, the issue of cleaning solar cells periodically is crucial. This research aims to develop a solar energy system with a flexible water cleansing system that operates remotely by employing the Internet of Things (IoT) technique. Due to the water circulation process, the system operates directly on the user's commands and does not need a continuous supply of water. The proposed system monitors remotely the dust on the surface of a solar panel by using a camera, which is working as a part of the IoT system, and it has been fixed in front of the solar. The proposed cleaning technique effectively reduces energy loss. Furthermore, the employed surveillance camera can be utilized efficiently for safety and security objectives in addition to monitoring the dust level.*

***Streszczenie.** Energia słoneczna jest jednym z ważnych źródeł czystej i odnawialnej energii i jest niezbędna do zaspokojenia przyszłego zapotrzebowania na energię. Mimo to nagromadzenie drobnego pyłu, ptasich odchodów i innych zanieczyszczeń unoszących się w powietrzu będzie utrudniać dotarcie światła słonecznego do powierzchni ogniwa słonecznego. Jest to poważny problem, ponieważ materiały blokujące światło działają jak impedancja zewnętrzna i zmniejszają wydajność systemów fotowoltaicznych zasilanych energią słoneczną. Zasadniczo, gdy na panelach utworzy się kurz, jego wydajność zmniejszy się o ponad 60%. W sequelu kluczowa jest kwestia okresowego czyszczenia ogniw słonecznych. Badania mają na celu opracowanie systemu energii słonecznej z elastycznym systemem oczyszczania wody, który działa zdalnie, wykorzystując technikę Internetu Rzeczy (IoT). Dzięki procesowi cyrkulacji wody system działa bezpośrednio na polecenie użytkownika i nie wymaga ciągłego dostarczania wody. Proponowany system zdalnie monitoruje kurz na powierzchni panelu słonecznego za pomocą kamery, która pracuje w ramach systemu IoT i została zamontowana przed panelem słonecznym. Proponowana technika czyszczenia skutecznie ogranicza straty energii. Co więcej, zastosowana kamera monitorująca może być efektywnie wykorzystywana do celów bezpieczeństwa i ochrony, oprócz monitorowania poziomu kurzu.(**Syatem czyszczenia paneli słonecznych wykorzystujący IOT**)*

Keywords: Remote-Cleaning, Dust accumulation ,Solar energy, Internet of things(IoT).
Słowa kluczowe: Zdalne czyszczenie, gromadzenie kurzu, energia słoneczna, Internet rzeczy (IoT).

1. Introduction

Solar irradiation is a crucial factor in the availability of solar energy and is required for solar energy system design[1]. solar radiation is the most significant source of natural energy by delivering a tremendous quantity of energy to the Earth. The total quantity of solar radiation is 1.7×10^{17} W, of which 34% is reflected, 42% is directly converted to heat, 23% is stored as water vapor, 1% is absorbed by wind and waves, and 0.023% is used by plants [2]. Consequently, photovoltaic (PV) technology can be used to transform solar energy into electricity [3]. However, the incoming irradiance to the cell is reduced owing to the accumulation of dust on the surface of the photovoltaic modules which produces power losses of 15% [4]. Based on spectrum and irradiance, the photovoltaic conversion efficiency, η_{PV}, is determined by the solar cell irradiated [5]. In the sequel, sun-tracking systems and cell cleaning systems are vital utilized techniques to increase the efficiency of photovoltaic cells [6].

Therefore, great efforts are adopted to overcome such deficiencies that may reduce the efficiency of solar systems. Partial shading on solar cells and its negative impacts, also how to mitigate these effects have received great efforts in recent studies. According to, Alers Glenn B.[7] reported the impact of dust buildup on solar PV module power production in the Eastern region of Saudi Arabia. Presented that the power drop of up to 50% when the surface of the solar cell remains dirty for more than six months. In addition, a solar tracker increases power production and contributes to a 50% reduction due to dust collection. As a result, Malay Mazumder [8] reported self-cleaning solar collectors, which are made of rows of transparent parallel electrodes embedded inside a clear dielectric film. The dust particles on the film's surface are electrostatically charged as a consequence of activating the electrodes by the phased voltage. Then, without any mechanical or water action, the electric field produces a traveling wave to remove 90% of such dust particles in about two minutes. On the other hand, Hussein A. Mohammed [9]controlled a windshield wiper tool with an Arduino Uno microcontroller, and it was activated when the output power fell to 50% of its rate value to increase the performance of solar panels. Whereas, Nurul F. Zainuddin [10] introduced a flexible cleaning tool by using the Internet of Things (IoT) mobile which monitors the amount of electricity produced by the solar cells. It has been approved by this work that the external resistance produced by dust will reduce the performance of solar panels by up to 22%. Nasib Khadka [11]used a robot moving back and forth to clean the solar panel surface by using a rotatory brush. Robot operation is monitored and controlled by the cloud. Moreover, sensors are used to monitor the performance of a solar farm located far away. Such a method can be implemented in a large-scale solar farm by joining the metal train rails to a long solar array.

In the sequel, eliminating the deleterious effect of the snow, dirt, dust, and bird droppings that effectively lower the panel's ability to absorb solar irradiance is crucial, this means that the surface of the solar panels should be cleaned regularly to eliminate the serious power loss of solar panel energy.

In this research, an Internet of Things (IoT) technique is employed efficiently to control a water cleaning system for the solar panel surface remotely and automatically. Furthermore, a camera is used on the panels to monitor the security situation in the region. In addition, a smartphone may control the water cooling system remotely if the panels need to be cleaned via a Wi-Fi connection. The proposed method is an efficient and low-cost scheme to clean, cool down, and monitor the solar panels remotely and automatically for physical large-scale projects economically and practically.

2. Internet of Things

The term "Internet of Things" (IoT) describes the quantity of actual physical objects linked to the internet that exchange information with other components[12]. This is a technology of the future generation that will soon be used in contemporary civilization. The Internet of Things (IoT) is the network or environment where internet-connected objects, such as sensors, are linked in real-time[13]. Additionally, sensors-equipped devices and items are linked to an Internet of Things platform, which combines data from many sources and uses analytics to communicate the most useful information with programs designed to meet certain requirements[14]. IoT has a wide range of applications in environmental monitoring, including ecological preservation, monitoring of extreme weather, and monitoring of dust in many nations across the world that are struggling with air pollution[15].

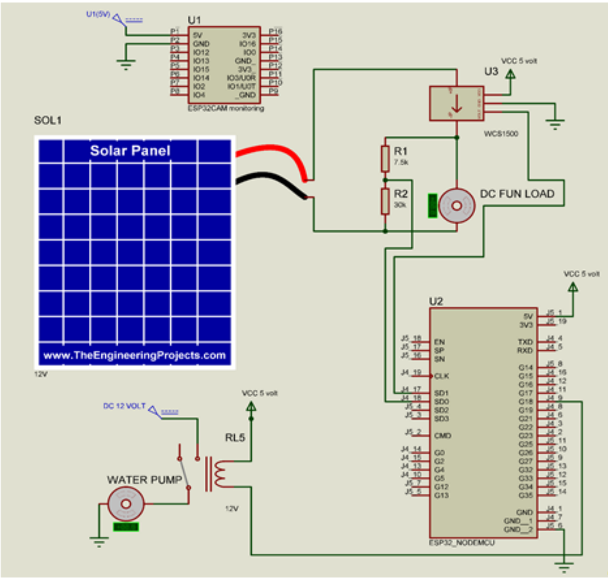


Fig.1. proposed system.

3. Proposed System

An ESP32CAM wireless security camera is connected to a Wi-Fi network configure the function with the Blynk application makes up the updated model. It is a platform that enables IoT projects and applications. A video feed by a used camera / which connects to the Internet through Wi-Fi is attached to a suitable water pump. A smartphone belonging to the authorized user may be used to remotely operate the pump. The user of the Blynk program may see the live video and determine whether or not, the panels need cleaning. The user may provide a direct order to the internet-connected controller to remotely start the water pump if they see dust gathered on the surface of the solar panels or if anything is preventing the solar radiation from reaching the panels. The water distributor positioned on top of the panels receives water by pumping it from a water tank, and the water cascades down and slides at the base of the panel. A water collector collects the water that slides down and returns it to the tank. In this instance, the solar panels have been cleaned and water recycling is accomplished. The created model shown in Fig. 1 provides the remote cleaning system with continuous water source delivery. The utilization of a power source that meets the needs of the employed components and provides electricity at varying consistent levels. The awareness of the current-voltage readings coming from the panel and being notified to the user through the phone is also considered. Furthermore, there is another benefit of the camera. It also monitors the solar real-time physical appearance especially if the solar farms are installed on the roof as they may be exposed to theft or vandalism.

The system created to meet the project's aim is shown in Fig. 2a below. The utilized control unit is shown in Fig. 2b. Water returns to the tank after sliding from top of the panel is shown in Fig. 2c .Fig. 2d depicts the system after the test.

Fig.2. Overall created System

4. Hardware Components

4.1. ESP32

The microcontroller known as the ESP32 was created by Espressif Systems. Shanghai is home to the Chinese corporation Espressif. The ESP32 shown in Fig. 3 below promotes itself as a self-contained WiFi networking solution that can execute standalone programs and act as a bridge between current microcontrollers and WiFi. The ESP32 didn't begin mass production until late 2016, therefore in the grand scheme of things, it is a brand-new addition to the processor lineup[16].Low-cost (around $5.99 US) ESP-32S ESP32 Development Board Wireless WiFi+Bluetooth 2 in 1 Dual Core CPU Control Board[17]. The ESP32 chip, designed for mobile, wearable, and IoT applications, uses a variety of proprietary software to achieve very low power consumption. Modern features like fine-grained clock gating, several power modes, and dynamic power scaling are also included in ESP32[18].

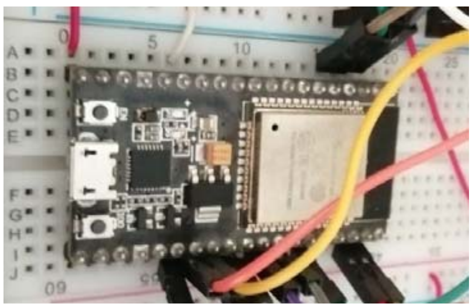


Fig.3. ESP32.

4.2. ESP32 CAM

An ESP32-S SoC from Espressif system, a powerful programmable MCU with built-in WiFi and Bluetooth, powers the board. The ESP32 development board with a built-in camera module, Micro SD card compatibility, and 4MB PSRAM is the least expensive (around $7). It takes additional soldering effort to add an external WiFi antenna for signal enhancement. Since the board lacks a standard USB connector, you will need to upload code to use an FTDI programmer as shown in Fig. 4 below, an add-on HAT, an Arduino UNO, and the Arduino IDE/ESP-IDF DEV tools. It is very suitable for many IoT and machine vision applications since it is a cheap board in a compact enough form size[19].

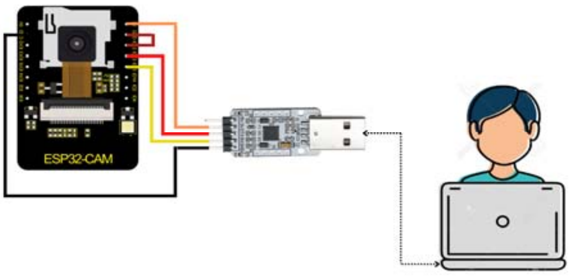


Fig.4. ESP32 CAM programming scheme

4.3. Water Pump

A cheap and compact submersible pump is shown in Fig. 5 below, the Ultra-Quiet DC 12V 3M 240L/H Brushless Submersible Water Pump is designed for quiet operation. It has a very low current consumption starting at 300mA and can handle up to 240 liters per hour. Simply attach a tube pipe to the motor output, immerse it in water, and turn it on. This heavy-duty cable-equipped pump has a 5mm DC female connection at the other end that may be used to connect it directly to a 12V power source. It is often used for both decorating and prototype projects. The pump features a mounting bracket and a lengthy cable that extends to 160 cm. The maximum pumping height is 300 cm[20].

Fig.5. Water Pump

4.4. Voltage Sensor

The voltage sensor is a compact, inexpensive module with a resistive voltage divider circuit at its core. It assists in dividing the voltage by 5. It reduces the voltage by 5 times, allowing us to measure up to 25V, the ESP32 ADCs have a resolution of 12 bits, and their overall reading ranges are from 0 to 4095 as shown in equation (1).

$$ADC_{Readings} = 2^{n-1} \quad (1)$$

where: $ADC_{Readings}$ – analog to digital conversion levels, n – number of bits

The system voltage affects the conversions from analog to digital. The 12-bit ADC in the ESP32 controller employs successive approximation to convert the analog voltage to digital since we mostly use it with a system voltage of 5V. This module shown in figure 6 below mimics a resolution as shown in equation (2).

$$ADC_{Resolution} = \frac{V_{Signal}}{ADC_{Readings}} \quad (2)$$

And the signal voltage can calculate according to the voltage divider rule as shown in equation (3).

$$V_{Signal} = \frac{R_2}{R_1 + R_2} \times V_{cc} \quad (3)$$

where: V_{signal} –signal voltage, V_{cc} –Supply voltage, R_1 –30 KΩ resistor, R_2 –7.5 KΩ resistor.

Making the input voltage detection module's minimum value 0.00122Vx5(for 25v)=6.1mV[21][22]. The Fig. 6 below shows the sensor used with the schema.

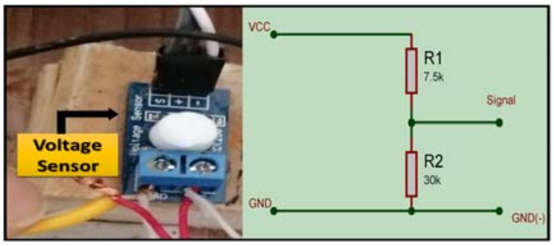


Fig.6. Voltage and current sensor

4.5. Current Sensor ACS712

Hall effects current sensor, model number ACS712. There are three graded currents available on the market: 5, 20, and 30. The 5 A current, which has the lowest rating, will be used for this task. The breakout board for the ACS712 ultra-cheap current sensor costs roughly $3.One drawback of this current sensor is that it requires cutting the wire we wish to use to measure current to connect this sensor in series[23]. The ACS712 current sensor is shown below in Fig. 7.

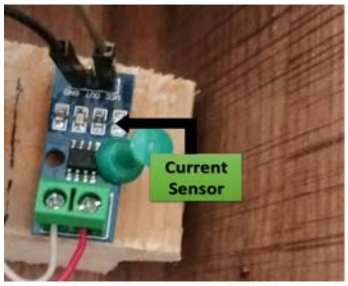


Fig.7. ACS712 current sensor

5. Software design

5.1. Blynk Platform

A software provider that offers an infrastructure for the internet of things is called Blynk. Blynk invented the no-code method of producing IoT apps in 2014 and became well-known across the world for its mobile app editor. Businesses of different sizes, from young startups to enormous corporations, exist today[24]. Additionally, since it is internet-based, it can monitor the system by connecting to the android internet. It has a straightforward, user-friendly design. Numerous lessons provided by the program allow the user to get more and more familiar with its operation[25].

5.2. Arduino IDE

Integrated Development Environment (IDE) is the official software that Arduino.cc released. It is primarily used for editing, compiling, and uploading code to Arduino devices. With this open source program, which is simple to install and easy to use for generating code while on the move, almost all Arduino modules are compatible[26], to program the control system used in this project and establish a Blynk connection, Fig. 8 below shows IDE has been used in code uploading.

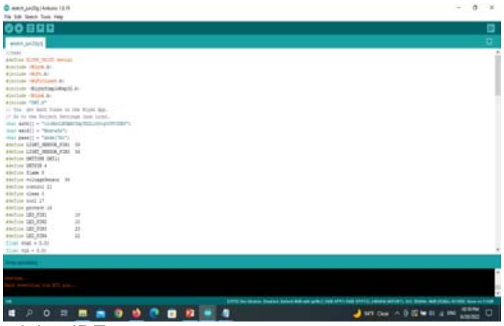


Fig.8. Arduino IDE.

6. Results

Through the camera broadcast, the dust gathered had been detected on the panel, and the voltage and current readings were taken in the late afternoon which indicated the diagram on performance dropdown, as shown in Fig. 9a. The next day, at the same time frame as the first instance, the second monitoring wear was performed, and to begin the washing and cleaning operation, a command was sent to the water pump through the smartphone and started to spray the water throughout the entire solar panel. The washing procedure will start when the water flows down from the top of the solar panel and the diagram shows instant improvement as illustrated in Fig.9b. Water is collected in the water collector at the panel's base, where it is then sent back to the tank. This technique is repeated until the dirt and dust have been removed from the panel. At this stage, we terminate the cleaning procedure and switch off the pump. The panel was seen by the camera as in Fig. 9c, after cleaning the panel of collected dust in the first scenario, the current and voltage values were recorded for the same period. The figures below demonstrate the significant rise in current and voltage levels before, during, and after the cleaning operation.

a) before cleaning b) during cleaning c) after cleaning

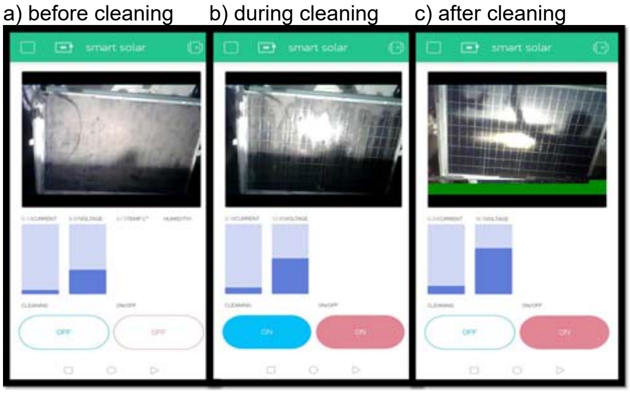
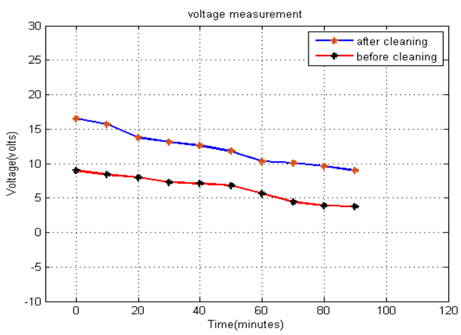


Fig.9. Cleaning Process.

a) Voltage measurements



b) Current measurements

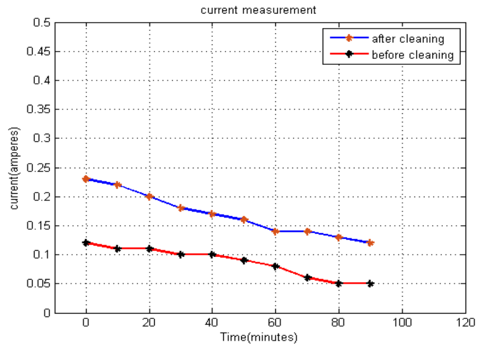


Fig.10. Measurement of electrical parameters.

In a different context, the reading of electrical parameters (Voltage and current) spent in both situations and under identical circumstances was recorded both times; the same load was being operated. The difference between voltage and current measurements taken before and after the panel cleaning procedure is shown in Fig. 10 a and b below.

7. Discussion

Some crucial elements may be explained after achieving the intended findings and the research of the objective. It is more efficient to use a surveillance camera than a dust sensor to monitor the collected dirt and dust on the solar panels, it is feasible to utilize one component to monitor many panels if attention is paid to its application for big systems. Considering that the dust sensor or cleaning robot is more costly than the camera, employing it instead of the camera necessitates utilizing more than one component for fewer panels. Additionally, unlike the dust sensor and cleaning robot, which cannot be used for safety reasons, the surveillance camera can be used in this manner. Remote water cleaning of the panel is superior to certain researchers' dry cleaning techniques. In addition to getting rid of the dust on the panels, water-cleaning lowers the temperature of the panels, which helps the system run more efficiently, particularly in hot weather. Consumer effort is minimal when using remote manual cleaning powered by “Internet of Things technology” IoT. The solar system user may periodically use a camera to monitor and decide whether or not the solar must be cleaned. . The cleaning procedure can be done independently and from any location, especially when the existence of the tank and the improved water circulation system negates the requirement for a water supply.

8. Conclusion

The efficiency of generating power is considerably increased by the solar panel cleaning technique. The efficiency of energy production is decreased when dirt and dust have been built up on the surface of solar panels, which limits the quantity of solar radiation that strikes the panels. In this study, it was discovered that the buildup of dust on solar panels' surfaces affected their ability to produce electrical energy by more than 60%. This research investigated a cleaning method based on the IoT, and the results were quite positive as seen in the illustrations. The cleaning procedure made up for the energy that was wasted. With the potential for remote cleaning, this job guarantees visual control over the system, raising its degree of effectiveness. The system may potentially be developed and expanded in this research to fulfill the needs of the user thanks to the usage of the ESP32 microcontroller. The project's possible drawbacks must be considered and referred to after the outcomes have been discussed and the project's benefits have been recorded. Long-term water cleaning procedures may result in dirt contamination of the water. As a result, the tank is filled with tainted water that cannot be used for cleaning. In the future, efforts may be made to address this issue. Water cleaning is the greatest method for removing dust from solar panels, and it is also the best approach to improve their performance. Particularly if you depend on technologies like the IoT and distant solar system connection. Consequently, particularly in hot weather, the water works to clean and cool the solar cell simultaneously, if the aforementioned information is considered, the suggested model does not economically harm the customer.

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