DESIGN AND IMPLEMENTATION OF SMART SOLAR PANEL CLEANING SYSTEM

Abstract

The sun is an abundant form of energy, and this solar energy can be harnessed with the help of solar panels by photovoltaic cells. Since the world is moving to renewable sources of energy, we find that solar energy is less harmful and abundant enough to be utilized for sustenance. Even though there are advantages on this matter the solar panel faces issues in terms of efficiency of collecting enough amount of solar irradiation. A lot of PV panels are used in the modern world. Now that they are gaining popularity so does their facility. There are lot of benefits when we consider this form of energy, but in terms of efficiency there seems to be issues, one of them is dust formation over the panel which causes the panel to become inefficient, as the major cause of the efficiency issue is the soiling and dust over the panels, it prevents the light radiation of sun to be passed through the photovoltaic cell and be converted to electrical form of energy. The proposed system is intended to implement a cleaning system that does not require any form of human intervention. A system which cleans based-on time schedule and a PIR sensor for analyses of dust to initiate panel cleaning.

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I. INTRODUCTION

Globally, low carbon dioxide (CO2) emission from energy conversion has been a major concern and the use of renewable energy is expected to be a prime solution. According to the Sustainable Development Scenario developed by International Energy Agency, it has been projected that till 2050, 32% of carbon emission shall be reduced by making the use of renewable energy sources replacing the fossil fuels [1-3]. Renewable energy is energy that is from renewable sources such as sunlight that can be naturally replenished. It provides an overall 19% of electricity production in the world [4-5].

The performance of solar cells differs by some site-specific influencing parameters like temperature, humidity, dust density, air mass, panel orientation. Additionally, these parameters might differ drastically in different seasons. Different forms of precipitation, clouds, and wind also affect year energy production from solar plants. Despite these factors, soiling is considered to be one of the major issues which block solar cells and reduces energy conversion efficiency directly. Moreover, dust accumulation most often leads to cell temperature rise resulting in the decrement in theefficiency indirectly.

Various studies have concluded that there lies a nugatory effect of soiling on the output of solar panels, mostly explained reduced solar intensity, and rise in cell temperature. Different dust prevention as well as cleaning technologies have evolved ever since PV plants have come into its use [6-12]. Robotic cleaners, electrostatic removal, self-cleaning layer, automated wafer cleaning are the current technologies which have been practiced so far and the selection of appropriatecleaning mechanism is a crucial task for the specific plant size and location. Beside the cleaning mechanism, the essence of the optimal time for cleaning is a concern which needs to be dealt with sincevisual inspection for decision making of cleaning shall not be appropriate in terms of energy economics [13-15]. The objective of this work is to achieve a to design and develop smart solar panel cleaning system that has: Periodic cleaning of PV panel with a fixed time schedules, to analyze and clean the system when required.

II. SYSTEM DESCRIPTION

The system includes solar panel, wiper for cleaning, PIR sensor, Arduino UNO, Node MCU, single channel relay module, DC Servo motor, LCD display, water pump and lithium-ion battery for storage.

1. **Construction:** The system starts with the Node MCU which operates the switching of the system.

   - The Node MCU is connected to the Relay module for the switching (ON/OFF) of the cleaningsystem.
   - The battery source is connected to the relay module.
   - The relay module is then connected to the Arduino UNO.
   - The Arduino UNO is connected to the DC servo motors; PIR sensor, LCD and DC waterpump through the relay.
   - The bread board here acts as a main mediator for the source to all the components

for theirconnection.

Fig 1 depicts the block diagram of the construction of the respected system and its flow.

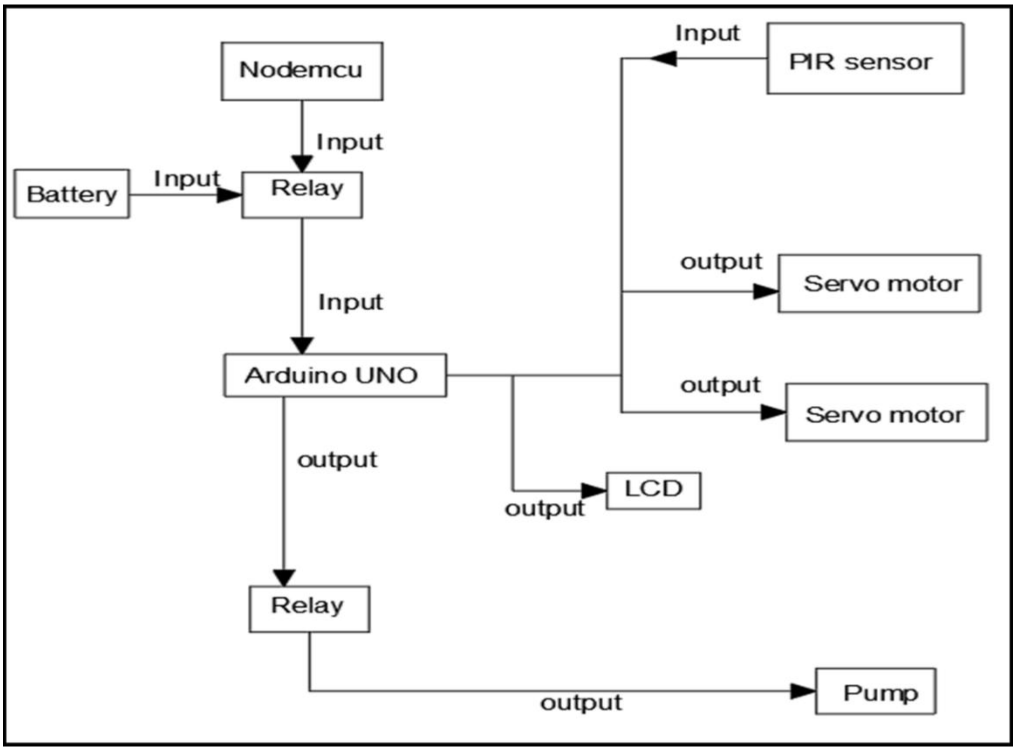

Figure 1: Block Diagram of Operation

2. **Blynk Application:** Blynk is a popular mobile application platform that allows you to easily control and monitor Internet of Things (IoT) devices using your smartphone or tablet. It provides a user-friendly interface for creating customizable interfaces and connecting them to variousIoT hardware platforms.

- **Introduction:** Blynk is designed to simplify the process of building IoT projects by providing adrag-and-drop interface for creating mobile apps. It allows you to control and monitor connected devices remotely, enabling home automation, sensor data visualization, and more.

- **Supported Platforms:** Blynk supports a wide range of hardware platforms, including Arduino, Raspberry Pi, ESP8266, ESP32, Particle, and more. This versatility allows you to choose the hardware that suits your project requirements.

- **Installation:** To use Blynk, you need to install the Blynk app on your mobile device. It is available for both iOS and Android platforms and can be downloaded from their respective appstores.

- **Creating Projects:** In Blynk, projects are created within the mobile app. You can start by creating a new project and giving it a name. Each project consists of a graphical interface called the "dashboard" that allows you to control and visualize data from your connected devices.

- **Widgets:** Blynk provides a variety of widgets that you can add to your project dashboard. Widgets are graphical elements that represent controls or displays. Some common widgets include buttons, sliders, gauges, graphs, LEDs, and LCD displays. These widgets can be customized and connected to the hardware pins or virtual pins of your IoT devices.

- **Connectivity:** Blynk uses a cloud-based infrastructure to establish communication between the mobile app and the connected devices. It provides a Blynk server that handles data transmissionand synchronization between the app and the hardware.

- **Virtual Pins:** Blynk introduces the concept of virtual pins, which act as a bridge between the app and the hardware. Virtual pins are software-defined pins that can be used to send or receive data between the app and the connected devices. They allow you to decouple the physical pin assignments from the app's interface, providing flexibility and easier app modifications.

- **Blynk API:** Blynk offers a comprehensive API that enables you to interact with your Blynk projects programmatically. The API allows you to send data, update widget values, and trigger actions remotely, expanding the capabilities of your IoT projects.

- **Blynk Libraries:** Blynk provides libraries for various hardware platforms that simplify the integration of Blynk into your IoT projects. These libraries include pre-built functions and examples that enable communication between your hardware and the Blynk app.

- **Advanced Features:** Blynk offers additional features to enhance your IoT projects, such as datalogging, push notifications, email alerts, and the ability to share projects with others. These features provide more control, automation, and collaboration options.

- **Blynk Community:** Blynk has a strong community of users and developers who actively share their projects, ideas, and solutions. The Blynk community forum and social media channels are great resources for getting support, inspiration, and learning from others.

III. NODE MCU CONTROLLED WITH BLYNK WORKING

Controlling a NodeMCU board using the Blynk application involves establishing a connection between the NodeMCU and the Blynk server, enabling you to control and monitor the board remotely. Here's a general explanation of how NodeMCU can be controlled using Blynk:

1. **Setup Blynk Account:** Start by creating an account on the Blynk platform (available as a mobileapp or web interface) and obtain an authentication token. This token is essential for theNodeMCU to connect to the Blynk server.

2. **Install Blynk Library:** Install the Blynk library in the Arduino IDE by navigating to "Sketch"
   ➔ "Include Library" -> "Manage Libraries." Search for "Blynk" and install the library.

3. **Hardware Setup:** Connect your NodeMCU board to your computer via USB and ensure it is properly recognized by the Arduino IDE. Select the appropriate board (NodeMCU) and the corresponding port in the "Tools" menu.

4. **Code Implementation:** Write the Arduino code using the Arduino IDE to program the NodeMCU. The code should include the Blynk library and the necessary functions to control the board's pins or modules. You'll need to include the authentication token obtained from the Blynk app or website in the code.

5. **Initialize Blynk Connection:** Within the code, initialize the Blynk connection by specifying theauthentication token and the communication protocol (e.g., Wi-Fi). Set up the necessary connection parameters, such as Wi-Fi SSID and password, to establish a connection between theNodeMCU and your local network.

6. **Map Blynk App Widgets:** Open the Blynk app on your mobile device and create a new project.Add the desired widgets, such as buttons, sliders, or gauges, to control or monitor the NodeMCU's functionality. Assign each widget a unique virtual pin number.

7. **Link Virtual Pins:** In the Arduino code, map the virtual pin numbers of the Blynk app to the corresponding physical pins on the NodeMCU. This mapping allows the app's widgets to interactwith the NodeMCU's pins or modules.

8. **Implement Blynk Functions:** Write the necessary functions in the code to handle Blynk app events. For example, when a button in the app is pressed, the corresponding function will be executed on the NodeMCU, allowing you to control the connected devices or perform specific actions.

9. **Upload and Run the Code:** Upload the code to the NodeMCU using the Arduino IDE. After successful uploading, the NodeMCU will start running the code and attempt to establish a connection with the Blynk server.

10. **Monitor and Control:** Open the Blynk app and connect to the project created earlier. You should now be able to monitor the NodeMCU's sensor data, control its outputs, or trigger specificactions by interacting with the app's widgets.

IV. PROTOTYPE DEVELOPMENT

The working prototype is shown in Fig. 2 and Fig. 3. Fig. 2 illustrates the top view of thecleaning system with solar panel. For this model, we can see that the system works on basis of time schedule as we had given an input of 10secs delay, we can find out that the system responds by the time we had given as input and after about 10secs the system pours in the water on the panel by the help of pump.

Figure 2: Top view of the proposed model

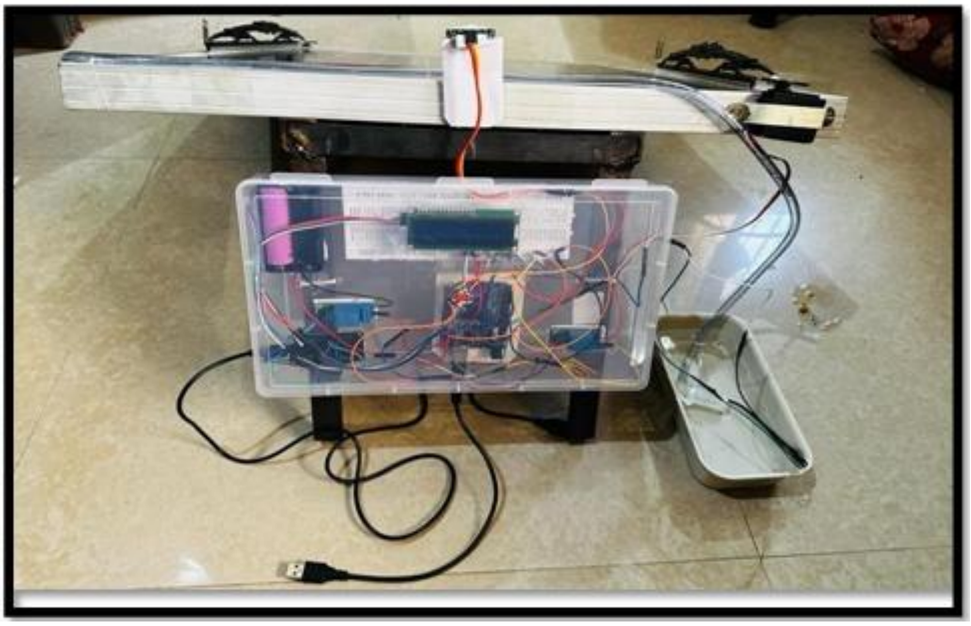

Figure 3: Assemble of Components.

This water helps in cleaning of the soil formation on the top of the panel and in about 1sec delay the servo motors which has wipers attached to it moves to the angle given as an input by the user this input of angle of rotation can be set based upon the dimension of the panel. The wiper does its action on time removing most dust and light objects (dry leaf) from the surface of the panel. And in analysis the PIR was set to certain angle and distance for detection of any proximity distortion, and when there was an object that interfered the PIR sensor, it analyzed and provided the input to the Arduino uno which in turn used the input for providing a signal to the output devices that is the servo motor whichinitiated.

The Node MCU can be used for switching. It can be done through various applications the applicationwe used was Blynk to achieve the ON and OFF operation of the system. The Node MCU does this operation of switching the device by the help of relay module which here acts as a magnetic switch, we used the template wherein we created a button for switching the device on the phone now that we switched the ON the button the cleaning system is ON, once when switched OFF the cleaning systemgoes to OFF state. This helps in maintaining and preventing overconsumption of the cleaning system if not required for operation.

V. ADVANTAGES

Smart solar panel automatic cleaning systems offer several advantages compared to traditional manualcleaning methods; they are:

1. **Improved Efficiency:** Dust, dirt, and debris can accumulate on solar panels over time, reducingtheir efficiency and power output. Automatic cleaning systems ensure regular and efficient cleaning, maximizing the energy production of the solar panels. By keeping the panels clean, these systems help maintain optimal performance and increase overall energy generation.

2. **Time and Labor Savings:** Manual cleaning of solar panels can be a time-consuming and labor-intensive task, especially for large-scale installations. Smart automatic cleaning systems eliminate the need for manual intervention, saving significant time and effort. Once installed, the system can operate autonomously, reducing maintenance requirements and freeing up resources for othertasks.

3. **Cost Efficiency:** While initial installation costs may be higher compared to manual cleaning, smart automatic cleaning systems offer long-term cost savings. They eliminate the recurring expenses associated with manual labor, such as hiring personnel or outsourcing cleaning services. Additionally, by optimizing energy generation, these systems contribute to maximizing the return on investment (ROI) of the solar panel installation.

4. **Increased System Lifespan:** Proper cleaning and maintenance can prolong the lifespan of solar panels. Automatic cleaning systems ensure regular and thorough cleaning, preventing the accumulation of dirt, grime, and contaminants that can degrade the panels over time. Byextending the lifespan of the solar panels, the overall system durability and performance are enhanced, providing long-term benefits.

5. **Remote Monitoring and Control:** Smart automatic cleaning systems often come with built-in monitoring and control capabilities. Through these features, users can remotely monitor the cleaning activities, performance, and maintenance needs of the solar panels. Real-time data and notifications enable proactive management, ensuring optimal

operation and facilitating timely maintenance or troubleshooting if required.

6. **Environmentally Friendly:** Solar panel cleaning systems that employ water-efficient and sustainable cleaning methods contribute to environmental conservation. They minimize water consumption, reduce chemical usage, and prevent the release of contaminants into the environment. By adopting eco-friendly cleaning practices, these systems align with the renewable and sustainable nature of solar energy.

7. **Enhanced Safety:** Manual cleaning of solar panels can pose safety risks, especially when dealing with installations at heights or difficult-to-access locations. Automatic cleaning systems eliminatethe need for workers to climb or access challenging areas, reducing the potential for accidents and injuries. This improves safety for both maintenance personnel and the overall operation of the solar panel installation.

VI. APPLICATIONS

Smart solar panel cleaning systems have various applications in different settings. They are:

1. **Utility-Scale Solar Power Plants:** Large-scale solar power plants consist of extensive arrays of solar panels. Cleaning these panels manually can be time-consuming and challenging. Smart cleaning systems offer a cost-effective solution for maintaining the cleanliness and performanceof solar panels in utility-scale installations.

2. **Commercial and Industrial Rooftop Installations:** Many commercial and industrial buildingshave rooftop solar panel installations. These installations are typically spread across a significant area and may be difficult to access for regular cleaning. Smart cleaning systems automate the cleaning process, ensuring optimal performance and reducing maintenance costs.

3. **Residential Solar Systems:** Homeowners with solar panel installations can benefit from smart cleaning systems. These systems offer convenient and efficient cleaning, saving homeowner’s time and effort. They also help maintain the performance and longevity of residential solar panels.

4. **Remote and Off-Grid Installations:** Solar panels in remote areas or off-grid installations often face challenging environmental conditions, such as dust, sand, or snow. Smart cleaning systems equipped with sensors and automated cleaning mechanisms can ensure reliable operation and maximize energy generation in such environments.

5. **Agricultural and Farming Applications:** Solar panels used for agricultural purposes, such as irrigation systems or powering farm equipment, can be exposed to dirt, dust, and debris. Smart cleaning systems help keep these panels clean, ensuring consistent energy supply for agriculturaloperations.

6. **Desert or Dust-Prone Environments:** Solar panels installed in desert regions or areas prone to high levels of dust accumulation can benefit from smart cleaning systems.

These systems automatically remove dust and dirt, preventing performance degradation caused by reduced sunlight exposure.

7. **Remote Monitoring and Maintenance:** Smart cleaning systems often come with remote monitoring and control capabilities. This feature is valuable for installations in remote orinaccessible locations. Operators can remotely monitor the cleaning activities, performance, and maintenance needs of the solar panels, allowing for timely intervention when required.

8. **Mobile Solar Installations:** Mobile solar installations, such as solar-powered vehicles orportable charging stations, can utilize smart cleaning systems to ensure optimal energy generation on the go. These systems provide automated cleaning functionality in a compact andportable design.

VII. CONCLUSION

The performance of the SPV panel is highly affected due to the dust deposition on the surface of solar panel. Moreover, there is a huge reduction of the corresponding output power generation and energy efficiency, especially when the duration of dust deposition is very long. Therefore, an efficientsolar panel cleaning system is highly essential to avoid the difference between the expected power output and actual energy yield from the solar power system. The developed method is most energy efficient as well as time efficient as in there is no necessity of human intervention over the operation of the system. It is low in cost and weight and easily scalable for commercial use. The entire system can be controlled remotely with the help of a mobile App. The proposed system uses a very soft pressured wiper, and it avoids scratches on the panel. The current version of the cleaning system is dry cleaning and water-based cleaning. Hence, it will not remove any hard stains on the panel.

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