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Design and Development of Solar Panel Cleaning Robot

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Abstract: The dust particles accumulating on the solar panels will prevent the solar energy from reaching the solar cells, thereby reducing the overall power generation. Power output is reduced as much as by 50%, if the module is not cleaned for a month. In order to regularly clean the dust, an automatic cleaning system which removes the dust on the solar panel is developed. In this paper, the problem is reviewed and the method for dust removal is discussed. A robot cleaning device is developed and it travels the entire length of the panel. A esp 32 cam wifi & l293d is used to implement robots control system. The robot provided a favourable result and proved that such a system is viable by making the robotic cleaning possible, thus helping the solar panel to maintain its efficiency.

Keywords: PV panels, Brush, DC motors, RF model, battery, Dust effects.

I. INTRODUCTION

Solar-based energy is gaining attention due to its cost-effectiveness and environmental benefits. It is a popular renewable energy source due to the low prices of solar panels and the lack of harmful effects of conventional methods. Solar systems use solar cells to convert sunlight energy into electricity, with four components: panels, battery, charge controller unit, and load. However, soiling, dirt, and residue particles can significantly degrade energy production. Residue deposition and dirtying of solar PV boards can lead to a decrease in efficiency, as sunlight irradiance disperses on the solar board's surface. The efficiency of solar panels decreases significantly when debris or residue film blockage prevents proper cleaning. Solar-based boards require regular cleaning to ensure optimal sun-oriented radiation penetration and battery charging. Traditional methods include brushing and water, while automated cleaning using robotics is being explored. However, manual cleaning is challenging in harsh desert conditions, expensive water and transportation, and uncertain future worker wages. Masuda et al. propose an electrostatic traveling wave cleaning system, which is currently under development and requires no consumables or mechanical components. This automated cleaning system maintains solar collectors clean throughout their working hours, ensuring maximum reflectivity and power generation. The goal is to design and develop an automated cleaning system for solar-based collectors, minimizing dirt and soiling effects and monitoring power production and surface cleaning using a mobile app.

A. Problem Definition

There is more than enough solar radiation available around the world to satisfy the demand for solar power systems. The proportion of the sun's rays that reach the earth's surface is enough to provide for global energy consumption 10,000 times over. On average, each square meter of land is exposed to enough sunlight to produce 1,700 kWh of power every year. Solar Panel has a huge effect on our world. It can helps our environment to be better without using other power generation plants that can harm the environment, but solar power plant needs to be cleaned at least every 3 days. It generally depends on the country for example in the Middle East, it needs to be cleaned every day so it will cost so much. There are a lot of techniques for cleaning the solar panels; our idea is to design a smart solar panel that cleans itself automatically and remotely in order to maintain a high level of efficiency of the solar panel.

B. Objectives

- To Design a Solar Panel Cleaning Robot.
- To develop a solar panel cleaning Robot.
- To Design a solar panel cleaning system which can increase the efficiency of solar panels.
- To Increase the use of solar panels.
- To Clean Solar Panel Simply by using automation.
- To minimize hazardous to the Human

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C. Project Specification

- The solar panel cleaning system operates automatically and remotely.
- Increase the efficiency at least by 10%.
- Recycle the cleaning water.
- An autonomous mechanism brush to clean the 100 W solar panel.

D. Need for Automatic Dust Cleaner for Solar Panel

Accumulation of dust on even one panel, reduces their efficiency in energy generation. That is why; the panel's surface should be kept as clean as possible. Current human based cleaning methods for Solar panels are costly in terms of time, water and energy usage. No automation has taken place in cleaning the solar panels, so, there exists a need for developing automatic cleaning machines which can clean and move easily on the glass surface of the panels.

II. LITERATURE SURVEY

E. Background of Study

One of the major issues that people face with the installation and the use of solar panels is the cost that is involved in it. But the cost can be drastically reduced by increasing the efficiency of each solar panel and hence reducing the number of solar panels that needs to be installed. Using less number of solar panels in order to get the required electricity will not only be cost efficient but will also help in having a positive impact on the environment. In order to improve the efficiency of the solar panels, there are two main aspects that need to be considered; the first aspect is the amount of light that falls directly on the solar, and the second aspect is how much of this light energy is capable of using effectively in order to generate power. The issue that is faced with the use of solar panels is the dust that forms over it. Dust on the cells of the solar panels reduces the efficiency of the solar panels to a large extent especially in Saudi Arabia where dust and sand storms are very common. Hence there will be an automated system that will periodically clean the solar panels in order to make sure that they perform at peak performance level. The use of right fabrication and controllers will help in making this project possible.

F. Present Theories and Practices

1. Project 1

Figure 1: Solar Brush UAV Panel

Photovoltaic cells produce electrical energy by absorbing solar irradiance, which is absorbed by the panels. Outdoor installations can reduce effective solar irradiance due to dust accumulation and obstructions like bird droppings, ice, and salt. To address these issues, cleaning systems are used. Autonomous cleaning robots are a leading technology, using soft brushes to clean solar panels without scratching the panels. Grando et al. (2017) surveyed solar cleaning projects and technologies, including solar brush UAV robots, Ecoppia E4, wash panels, and Nomad cleaning systems. The solar brush robot uses air pressure and gentle rubbing to clean the panel, reducing the risk of damage.

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2. Project 2:

Figure 2: Ecopia Solar Cleaning System

The Ecopia solar cleaning robot utilizes a guiding railing to clean solar panels horizontally and top-down. It sweeps microfiber brushes connected to its head, cleaning the array surface. The system has a solar cell-charged battery, allowing it to clean panels at night and can be controlled via the internet.

3. Project 3:

Figure 3: horizontal Brush Cleaning System

Washpanel solar cleaning systems utilize water and a horizontal brush to clean solar panels. The system moves, allowing water to sprinkle on the panels and the brush to remove mud. The nomad cleaning system, similar to the Ecopia system, has only two motors for horizontal movement. The brush revolves around its axis in a circular motion, sweeping across the panels to remove dust and blockages. This fully automated and intelligent system can be controlled remotely and configured for various cleaning schedules.
Project 4:

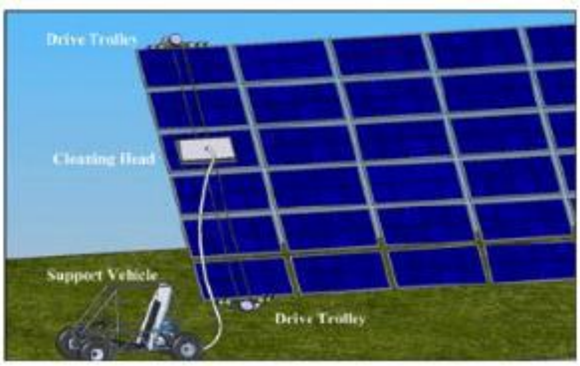

Figure 4: Support Vehicle Based Solar Panel Cleaning System

Sweezey et al. (2009) has produced another kind of robotic solar panel cleaning system which utilizes a support vehicle in addition to the cleaning head and moving trolleys, as shown in Figure 5. Similar to NOMAD and Ecopia systems, cleaning head sweeps the brushes on the surface of the panel. To move the drive system, DC motors of 12 volts are used.

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The upper and lower trolleys are capable to move in different positions and direction. This feature allows the system to clean the panels in square wave pattern.

III. METHODOLOGY

The solar panel cleaning robot is designed to remove dirt and dust from solar panels, allowing them to absorb the maximum amount of energy. The system consists of two main parts: the cleaning robot and a brush and sping. The cleaning robot moves from one panel to another, covering the entire length of the panel. The brush attached to the robot removes dirt and dust. The robot is connected to ESP 32 WIFI, controlling its operations and movement.

The main criterion of the cleaning system design is its ability to clean multiple panels in a solar farm using a single robot, making it simpler than having multiple robots working simultaneously. However, cleaning solar panels is often more laborious and expensive. This paper investigates the effects of accumulated dust on solar panel performance using experiments in dusty atmospheres of different levels. An auto cleaning robot is also proposed to work as an auto cleaner on the solar panel.

The carrier robot and cleaning robot move towards the solar panel and stop its movement by sensing the panel. The carrier robot sends a signal to the cleaning robot, which travels the entire length of the solar panel in both forward and backward directions and cleans the panel for the specified time duration. After cleaning, it returns to the carrier robot and continues the process.

G. Block Diagram

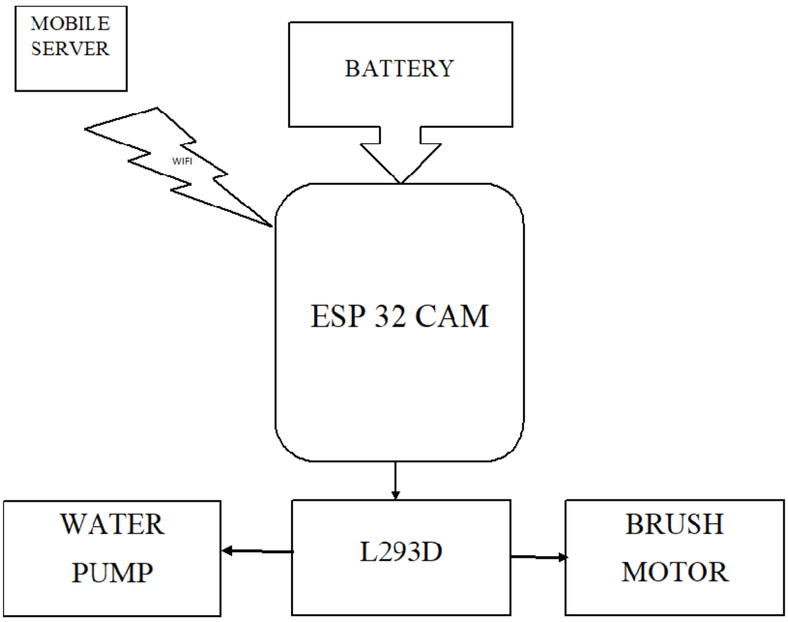

Figure 5: Block Diagram for Proposed System

H. Software Installation and Working

4. Embedded C

The C Standards committee developed a set of language extensions for the C programming language called Embedded C to address difficulties of compatibility between C extensions for various embedded devices. In the past, supporting exotic features like fixed-point arithmetic, several different memory banks, and fundamental I/O operations required nonstandard additions to the C language.

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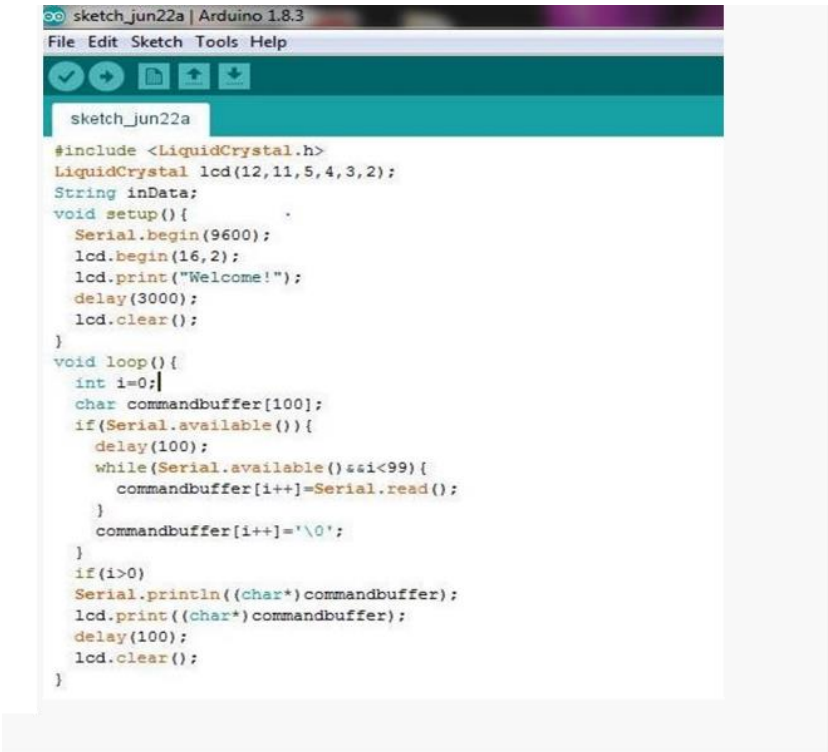

Figure 6: Creating Sketch in Arduino IDE

To function properly, the LED must be connected to pin 13 and ground. A C++ program is written to a temporary file with an include header and a simple main() function. The Arduino IDE uses the GNU tool chain and AVR Libc for compiling programs, while AVR guy uploads them to the board. A third-party graphical development environment called Mini blog is available for educational use under an open-source license.

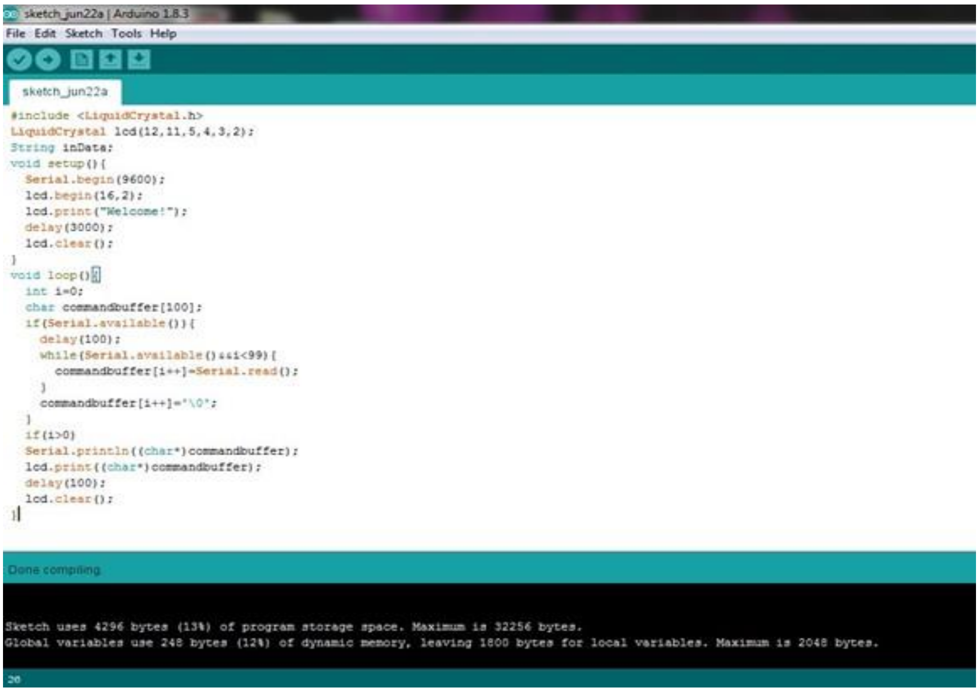

Figure 7: Program Compilation Window

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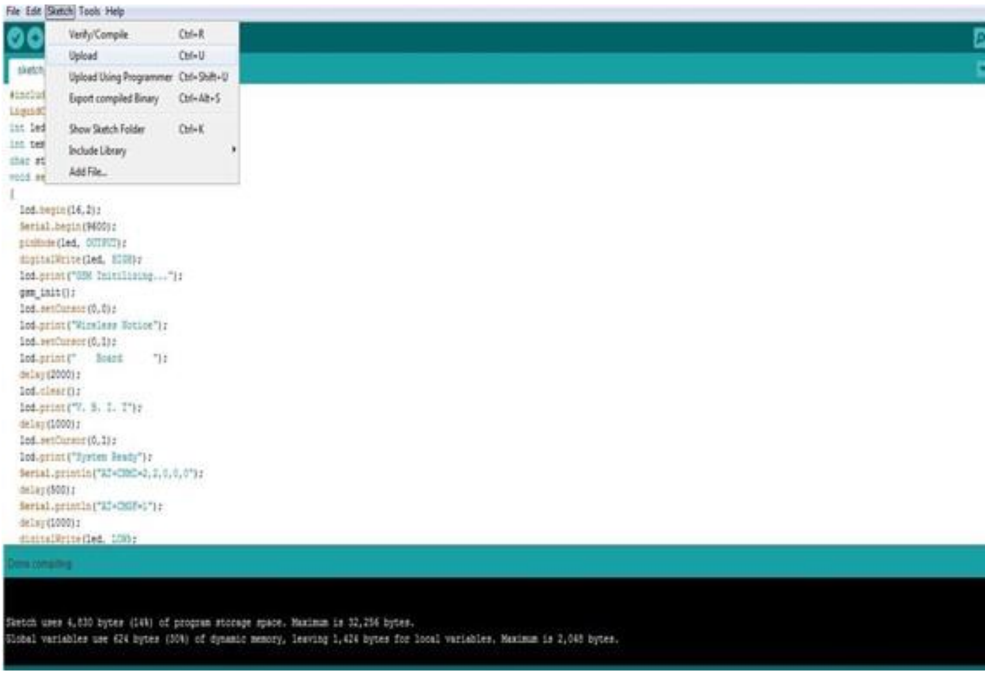

Figure 8: Uploading Program to Arduino Uno Board

IV. COMPONENTS USED

I. ESP32 CAM

Figure 9: ESP32 CAM

*Specifications

Table 1: Specifications of ESP32 CAM

SPI Flash	Default 32Mbit
RAM	520KB SRAM + 4MB PSRAM
Bluetooth	Bluetooth 4.2 BR/EDR and BLE standards
Wi-Fi	802.11 b/g/n/
UART Baudrate	115200 bps
Image Output Format-	JPEG (OV2640 support only), BMP, GRAYSCALE
Spectrum Range	2412 ~2484 MHz
External Storage	micro-SD card slot up to 4GB.
Camera	-

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J. L298D Driver Module

The L298N is an integrated monolithic circuit in a 15- lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver de-signed to accept standard TTL logic level sand drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the in-put signals .The emitters of the lower transistors of each bridge are connected together rand the corresponding external terminal can be used for the connection of an external sensing resistor. An additional Supply input is provided so that the logic works at a lower voltage.

DC Motor

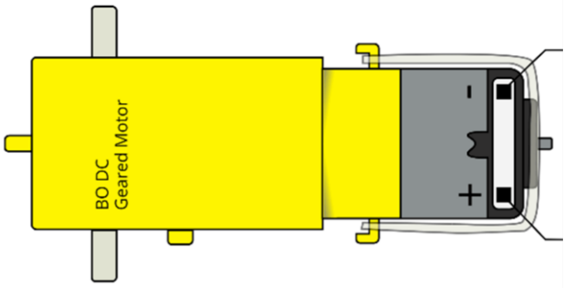

Figure 10: DC Motor

*Specifications

Table 2: Specification of DC Motor

Operating Voltage (VDC)	3~12
Shaft Length (mm)	7
Shaft Diameter (mm)	(Double D-type) 5.5
No Load Current	40-180mA.
Rated Speed (After Reduction)	100 RPM
Rated Torque	1KgCm
Weight (gm)	30
Dimensions in mm (LxWxH)	42 x 23 x 55
Gearbox Shape	L-Shape

Water Pump

Figure 11: Water Pump

*Specifications

Table 3: Specifications of Water Pump

Operating Voltage (VDC)	3 to 6
Operating Current (mA)	130 to 220
Flow Rate (L/H)	80 to 120
Maximum Lift (mm)	40 to 110
Continuous Working Life (hours)	500
Driving Mode	DC, Magnetic Driving
Material	Engineering Plastic
Outlet Outside Diameter (mm)	7.5
Outlet Inside Diameter (mm)	5
Weight	20 grams

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V. RESULT AND DISCUSSION

The feasibility of the designed system is verified through robot simulations, which demonstrate the reliability of the adopted control strategies. Proteus software was used to simulate the system, which consists of three steps with a switch to control each step. The process starts with the motor moving forward and the brush cleaning, followed by the motor reversed and the process done in reverse. The battery is charged by the power supply of the PV.

For real verification, the station was controlled using Arduino control software. The mobile robot was tested for its suitability in cleaning solar panels, demonstrating good mobility and the ability to pass over the panels. The robot successfully completed the cleaning operation, including forward and backward motions along the rail, according to the Arduino program. The cleaning brush also effectively cleaned hindrances like residue and dry leaves.

The IP camera is used to monitor the cleaning operation and conditioning of PV panels. It is connected to the internet and can display on Android and PC Windows systems. It can also be used for video recording and image capturing during cleaning. All extracted data is documented and stored in a file, confirming its reliability during monitoring the cleaning operation.

VI. CONCLUSION

The cleaning technology of the Solar PV panel is extremely improved the efficiency of power generation and enhanced panel durability. The dust and residue deposition minimize the radiation falling on solar cells and in turn reduce electricity generation. In this study, a cleaning robot system was developed and implemented. The cleaning robot was tested and achieves successful result. Both of produced current and of efficiency rating was improved by using the developed system. The remote monitoring based on IOT ensures. Comprehensive monitoring and increase the efficiency rate of the system. Currently, this robot is not for commercial use and there is future work of development to add more functions for different applications. With more advances of technology, more developed and efficient cleaning methods are taking their way to practical use to reduce the power losses due to dust accumulation on the panel surface. Therefore, the automation of solar power plant will support and enhance the decision-making of large scale solar fields.

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