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SOLAR PANEL CLEANING ROBOT

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Abstract: - *As electricity costs rise and environmental concerns over fossil fuels grow, more and more renewable energy sources, including solar power, are being used. Solar panel arrays are the primary means of obtaining solar power. Dust and debris buildup on even one panel significantly lowers the panels' ability to generate electricity, underscoring the importance of maintaining a clean surface for the panels.*

The labor-intensive cleaning techniques now used for solar arrays are expensive in terms of time, water, and energy used, and they are not automated. This research presents a revolutionary design for the first-ever human portable robotic cleaning system for solar panels. The system is able to clean and move at several angles, from horizontal to vertical, over the glass surface of a solar panel array. To accomplish this, a microcontroller board is used.

The Arduino Uno, which is employed in this specific model, makes it simple to operate every component. As a result, it aids in our understanding of the necessary parameters to address the efficiency shift caused by cleaning the solar panel arrays.

Key Words: Solar Panel, Cleaning Robot, Sensor based Robot, Automated Cleaning.

1. INTRODUCTION

Aspects pertaining to energy are becoming increasingly significant these days. These include, among other things, the consumption of non-renewable resources, the environmental impact of pollution emissions, and the prudent use of resources. Instead of depending on generators or other regular sources of electricity, the majority of industrial applications employ solar panels as their electrical power source. These factors have led to a global increase in interest in energy conservation and sustainable energy production. Over the past ten years, there has been a notable expansion in the solar photovoltaic (PV) market due to growing interest in renewable energy. Improving solar power generation efficiency is urgently needed.

The surface of the photovoltaic cells must be clear of dust and free of any particles that could impede the flow of photons in order for the cells to perform at maximum efficiency with zero energy loss.

As a result, contamination of solar panels rapidly reduces efficiency since any debris or impediment in the path of the sun's rays interferes with their ability to capture solar energy.

The primary issue affecting a photovoltaic panel's efficiency is dust, which, depending on the location, can reduce the panel's effectiveness by up to 25% to 30%. Dust collection on a photovoltaic (PV) module can range from 80 to 300 mg/sq per day, with an extra 0.4% to 0.7% power loss occurring for every 100 mg/sq of dust deposition. following exposure to the surrounding dust. Even if dirt and bird droppings don't cause much of a problem, solar panel efficiency drops by 15% to 20%. For the solar panel to continue producing at the same rate for a longer amount of time, periodic cleaning is therefore required.

Compared to hand cleaning and existing mechanical alternatives, a well-designed and efficient robotic equipment can clean expansive parks while using less water. Water is necessary for the cleaning process since it increases efficiency, and most commercial crystalline silicon solar cells are known to exhibit an acceptable current voltage characteristic at lower temperatures.

This has to do with how the bot uses water to spray the photovoltaic cells, increasing their effectiveness by almost 15%. Automation is basically necessary for this procedure because it improves utilisation, facilitates better human handling, and minimises manual inspection. As a result, there is a possibility that the system will be cleaned with auto lining features.

An extremely significant benefit of an automated robotized response to the question about solar panel cleaning is the controlled process's superior cleaning speed, robustness, completeness, and test-retest dependability when compared to conventional approaches.

2. METHODOLOGY

An automated solar panel cleaning bot is a cleaning tool that uses the least amount of water possible to clean solar panels. The cleaning head of the bot is designed to efficiently remove dust and dirt from the solar panel's surface. To lower the possibility of damaging the glass surface of the solar panel, an automated solar panel cleaning bot is moved around the arrays using wheels and track belts. It runs on a 12V lead acid battery that may be used for three hours after a full charge. When the robot approaches the edge of the solar PV array, it has the ability to alter its direction of motion. Up to a 40 degree inclination, the bot can clean.

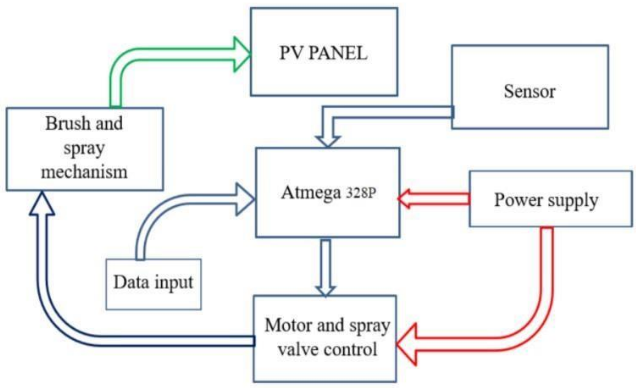

Fig -1: Basic Block Diagram

3. COMPONENTS

3.1 Microcontroller

The microcontroller used in this project is an ATMEGA328P. Microchip makes this high-performance, low-power controller. It is essentially an Advanced Virtual RISC (AVR) microcontroller, and it is an 8-bit microprocessor. Up to eight (8) bits of data can be supported by it. 32KB of internal RAM is integrated into the Atmega328P.

Numerous more features are present in this microcontroller, including a 1KB Electrically Erasable Programmable Read-Only Memory (EEPROM). The Static Random-Access Memory (SRAM) of the Atmega328P is 2KB. Good performance, low power consumption, a separate oscillator in the real timer counter, six PWM pins, a programmable Serial USART, and a programming lock for software security are some of these advantages. It runs in the 3.3V to 5.5V range.

3.2 Lead Acid Battery

In this project, a 12V/7Ah lead acid battery is employed. Lead-dioxide cathode, sponge metallic lead anode, and sulfuric acid solution electrolyte make up lead acid batteries. There is a 2V cell voltage. Since the energy that can be drawn from the battery is calculated by multiplying the battery capacity by the depth of discharge, the depth of discharge and battery capacity together constitute a fundamental parameter in the design of a battery bank for a photovoltaic system.

3.3 DC Motor

The movement of the bot is powered by a 12V, 300 RPM DC motor. A low-cost, high-quality DC geared motor is the 300RPM Series DC motor. Steel pinions and gears provide superior wear and tear characteristics and a longer lifespan. (ii) The motor is built with strength. The shaft has long-lasting metal bushes. It has high-quality gears included. Additionally, the shaft features a hole for improved connection.

Motor Driver

The motor driver utilised in this project is RKI 1004. The motor drive is a H bridge. An electrical circuit known as a H bridge is used to change the polarity of a voltage applied to a load. In robotics and other applications, these circuits are frequently employed to enable DC motors to move forward or backward.

3.4 Ultra Sonic Sensor

The ultrasonic sensor used in this experiment is the HC-SR04. The pin names for the 4-pin HC-SR04 Ultrasonic Sensor module are Vcc, Trigger, Echo, and Ground, in that order. This sensor is widely utilised in situations where it is necessary to sense objects or measure distance. The ultrasonic transmitter and receiver are formed by the module's two eyes-like projections at the front. The formula that the sensor utilises is

$$\text{Distance} = \text{Speed} \times \text{Time}$$

3.5 Water Pump

When cleaning the PV panel, a water pump is employed to spray water through a nozzle. Here, a diaphragm water pump with a 12V DC 100PSI pressure is utilised.

4. DESIGN

4.1 Design of Frame

The bot's frame is made of a 2.44 x 1.22 x 1 mm metallic sheet. Industrial solar panels typically measure 77 by 39 inches (195.58 cm by 99.06 cm). Therefore, in order to balance efficiency and weight, the frame is designed to be 50 cm long and 35 cm wide. Therefore, the entire panel can be cleaned by the bot. Reduced size results in longer cleaning times, and excessive weight reduces the bot's efficiency. As a result, this is the bot's ideal size and works with panels of any size.

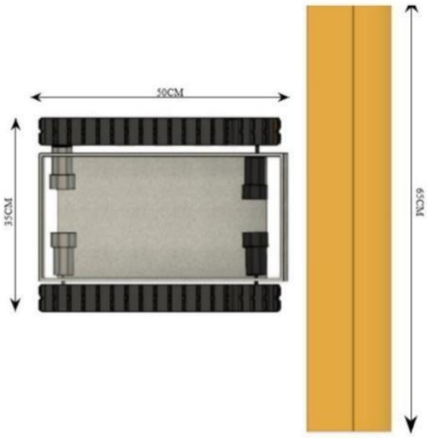

Fig -2: Design of Frame

4.2 3D Model

Fusion 360 is used to create the automated solar panel cleaning robot's 3D model. The cleaning robot is made up of a frame that holds up the entire apparatus. The head of the frame features a brush that is used to clean the panel's surface. The bot's motor and other components are housed inside the frame's framework.

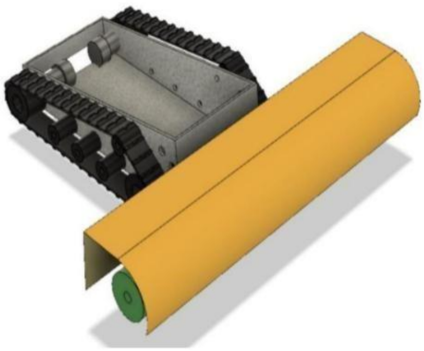

Fig -3: Top Side View

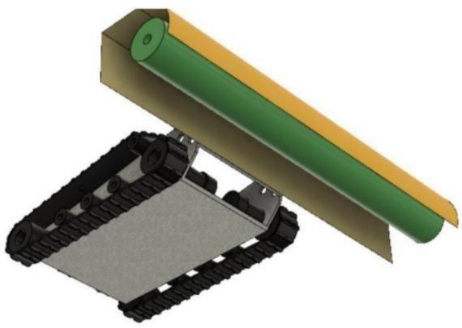

Fig -4: Bottom Side View

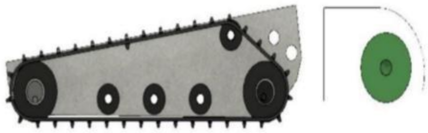

Fig -5: Side View

4.3 Software Development

To save cleaning time and power consumption, the new software is designed to trace a path from one edge to the other on the surface of PV panels. To increase the robot's stability, a vertical path was selected for it.

A force from the side will push the robot down if the path is designed to be horizontal. The robot will reverse its direction of motion when it senses the end of the panel. When it's done, it will either be on the upper right side or the lower right side of the panel. After that, the robot waits to resume its next cleaning cycle.

4.3.1 Motor - Arduino Interfacing

The motor and Atmega328P interface is the first step in the software development process. The motor driver, RK1 1004, assists in this process. While the direction of the motor's spinning can be altered by changing the direction of current flowing through it, the speed of a DC motor can be varied by applying different DC voltages. We can apply different voltages by using the PWM approach. H-bridge circuits or motor driver ICs that use the H-bridge approach can be used to reverse the current.

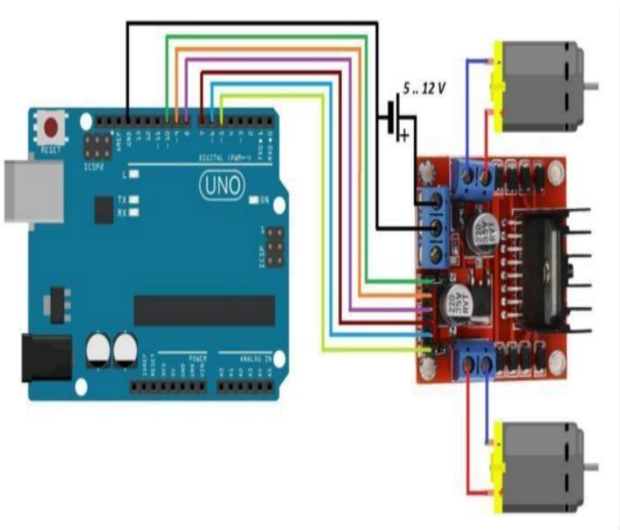

Fig -6: Motor – Arduino Interfacing

5.3.2 Switch Keypad – LCD Display – Arduino

Interfacing

The LCD display and switch keypad interface with the Atmega 328P is the next step in the software development process. This is done so that the length and width of the solar panel that has to be cleaned can be entered. The panel's length and width are entered using a switch keypad, and the results are shown on the LCD display. Using C programming, the switch keypad, LCD display, and Atmega328P are interfaced.

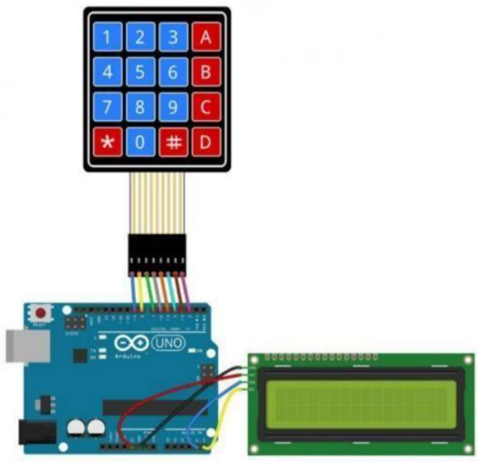

Fig -7: Switch Keypad – LCD Display - Arduino Interfacing

4.4 Hardware Development

The panel cleaning bot devised in this instance consists of a cleaning head that travels around the panels utilising track belts and a stainless steel rod. This design was chosen due to its resilience, simplicity, and lower cost of ownership. The movement is aided by wheels and manual force to reduce the chance of scratching the glass surface. This design's test-retest capability enables reasonable continuous functionality across a large variety of array dimensions. Despite the fact that no two panels or arrays are the same size, the system's ideal size allows for flexibility. Because the robot can traverse the side borders between the panel frames, the panel columns have continuous travel.

This robot's chassis is constructed from aluminium. To retain motors in the correct place, it comprises of four L-shaped motor mountings. Additionally, the chassis offers a sturdy framework for the battery and other electronic components. The nylon brushes are 120 g in weight, hollow cylinders measuring 160 mm in length and 75 mm in outer and 11.8 mm inner diameter. The filaments in these brushes are nylon. There are three held together and used brushes. The brushes are firmly packed to provide an effective deburring effect.

A DC geared motor that produces 10 kgcm of torque is used to turn the brushes. A 12V battery is required for the motor to run at its best. Mounting is used to secure the motor. In addition to scouring the unclean surface, we may need to wash it with high-pressure water directed in a specific pattern at the surface. This is made possible by the nozzle.

4.5 Design Calculation

- Speed of bot = 9 cm/s
- Length of brush = 65 cm
- Area covered in 1 sec = 0.09 x 0.65
  = 0.0585 Sqm
- Area covered in 1 hour = 0.0585 x 60 x 60
  = 210.6 sqm
- Total working hour of bot per full charge
  = 3 hours
- Area covered in 3 hours = 210.6 x 3
  = 631.8 sqm

5. WORKING

To turn the brushes, a DC geared motor with a torque output of 10 kgcm is employed. To drive the motor as efficiently as possible, a 12V battery is needed. The motor is held in place by mounting. We might also need to apply a high-pressure water wash in a particular pattern to the dirty surface after scrubbing it. The nozzle makes this possible.

The robot advances and wipes the solar panel's surface clean. The motor is stopped by the ultrasonic sensor as the robot approaches the end of the panel, detecting the panel's edge. Then, using one set of motors at a time, the bot modifies its direction. The bot carries on cleaning once the direction is altered and advances further. The solar panel's whole surface is cleaned as the procedure proceeds. With the aid of a nozzle and water pump, the bot sprays water while running on a 12V lead acid battery.

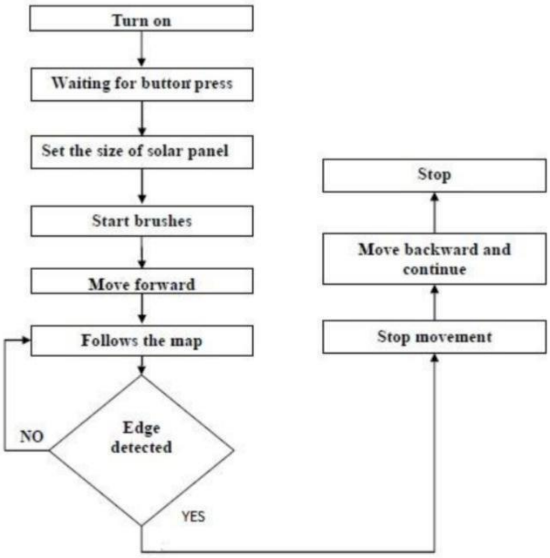

Fig -8: Flowchart

The bot's movement pattern is designed to be zigzag. In order to cover the full panel, the bot follows the path. The programme takes into account the following:

1.The bot proceeds along the path depicted in the picture.

2. To prevent it from falling off, the margins of the PVs are recorded using ultrasonic sensors.

3. After the cleaning procedure is complete, the motor is stopped.

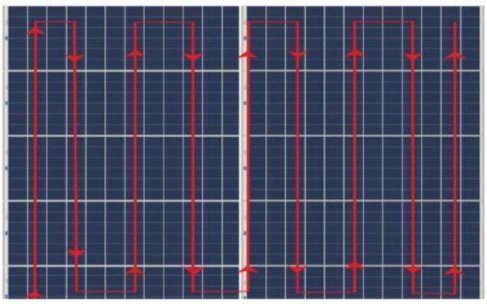

Fig -9: Moving Path of the robot

When the ultrasonic sensor detects the edge of the panel, the table shows the robot's direction and movement. The robot's direction can be altered in a few ways.
• At first, the robot will go straight ahead when the sensor is low.
• In the second method, the sensor rises when it detects an edge. The robot will halt, go a predetermined distance in reverse, turn 180 degrees to the right, and then proceed straight ahead for a predetermined distance.

• After that, the robot will make a 180-degree spin to the right and continue straight ahead until the ultrasonic sensor turns high.

• The movement keeps on until the panel's lower edge. When the sensor rises, the robot will halt, reverse, and turn 180 degrees to the left before continuing straight ahead for a predetermined distance.

• The robot will then make another 180-degree spin to the left, and the process will repeat.

• The procedure doesn't stop until the robot completes the designated path.

Table -1: Motor Movements

Robot Movement	Left upper Motor	Left lower motor	Right upper motor	Right lower motor
Forward	Clockwise	Clockwise	Clockwise	Clockwise
Stop	Stop	Stop	Stop	Stop
Reverse	Anticlockwise	Anticlockwise	Anticlockwise	Anticlockwise
Right turn(180°)	Clockwise(right)	Clockwise	Clockwise(right)	Stop
Left turn(180°)	Clockwise(left)	Stop	Clockwise(left)	Clockwise

6. RESULT

The solar panel is effectively cleaned by the bot to get rid of the dust and debris that have accumulated on its surface. When compared to manual cleaning, the cost of cleaning can be reduced by 80% by using bots. The effectiveness of the solar panel is increased by approximately 25% by cleaning it to get rid of dust and debris. It uses 90% less water to remove dust than other methods. It is compatible with nearly all panel sizes found worldwide.

(i) Manpower reduction: Compared to manual cleaning, robot cleaning of solar panels takes less time. In the end, it takes less time overall to clean every pane(ii)Effective housekeeping:

According to our research, there are numerous issues with manual cleaning, including its inability to remove materials and sticky dust from surfaces. This hoover robot eliminates those sticky particles and debris.

(iii) Increase in Power Generation: After operation, this robot easily and quickly provides a cleaned surface with less effort. As is well known, sunlight cannot reach the surface because of dust buildup. The impartation of sunrays increases on a cleansed surface. Thus, panels' efficiency rises by roughly 25%.

(iv)Water usage reduction: The current cleaning system uses more water to clean. Water consumption in this proposed system can be managed with a valve and nozzle.

(v) Adjust to each panel: This lightweight gadget fits every panel. This robot can clean nearly any size panel. (vi)Diminution of expenses per unit: It saves 80% on cleaning costs because it can cover a vast area for a low cost while using less water.

7. CONCLUSION

Any type of biological or chemical dust that accumulates on the panel reduces the output power of solar photovoltaic cells by interfering with their performance. PV performance can be restored by removing the heavy layer of dust deposition. Therefore, maintaining and cleaning solar panels is a crucial part of their performance. An 8-panel array's efficiency has been seen to increase by 30% to 33%; thus, we can observe that it will be more useful in solar parks with significantly bigger cell counts. Thorough cleaning is very beneficial because even a single panel obstructed by dust can reduce the array's overall performance.

Considering that the cells are connected in series, it is crucial that they all function at maximum efficiency. Both the natural technique and the manual way are now used to clean PV panels. Given the benefits and drawbacks of the various solar panel cleaning techniques now in use, it is believed that an automatic brush type system would be best because it uses either very little or no water to remove dust off solar panels. It may be developed domestically and is inexpensive as well. It functions as an auxiliary unit of the current solar photovoltaic system and is also in operation.

7.1 Future Scope

Long-term cost reductions that our project asserts. Even if everything about our project went according to plan and operated well, there is still much that could be done to increase its efficiency and marketability. The system will be optimised in the future to be lighter, smaller, easier to ensemble in larger volumes, and more environmentally friendly. More attention will be paid to the auto-lining features, robustness, speed, and general intelligence enhancement of the bot. Installing proximity sensors and a thermal camera module makes it easier to inspect solar panels and enhances interaction with each panel. It would be difficult to clean multiple arrays at once, but design should be more universal to accommodate nearly all panel sizes

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