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SOLAR PANEL CLEANING ROBOT

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Abstract: The project is about the design and development of a solar panel cleaning robot.
The main object of this design prototype is to clean the solar panel using an electronic tool. Solar energy, which is one of the best renewable energy resources to generate electricity. It has an important role in meeting the electrical energy demand of our globe. In recent years, many countries have established their energy policies based on solar energy, and researchers have been working on solar panel efficiency, that how can we maximize the efficiency of the solar panel. The energy extracting from the sun converted into electrical energy through solar panels. Continuously extracting energy from the sun reduces installation costs and makes it easier to meet the demanded electrical power. Some physical conditions like muddy rain, snow, grim and dusting place between the solar panel and the sun reduces the electric power generation which can be technically produced by clean the surface of solar panel. Hence In this study, we have designed a solar panel cleaning robot and tested in real time.

Introduction: The sun emits a tremendous amount of energy, resulting in abundant availability of solar energy in nature. If we could harness all this solar energy and convert it into usable forms, it would be more than sufficient to meet the world's energy demand. However, this is not currently feasible due to atmospheric conditions such as the presence of clouds, dust, and variations in temperature. To convert solar energy into a more usable form, solar panels are commonly used. Among the various alternatives, the photovoltaic method of extracting power from solar energy has been considered an excellent source for meeting the ever-increasing energy demand.

However, the efficiency of solar panels is limited by natural conditions, making it crucial to consider parameters such as dust, humidity, and temperature. In this context, a project has been undertaken to study the efficiency of solar panels with and without dust accumulation. The project involves the design and implementation of an Arduino-based automatic dust cleaning system. Previously, cleaning the panels was done manually, which had several disadvantages, including the risk of staff accidents, panel damage, movement difficulties, and poor maintenance. The automatic dust cleaning system aims to overcome these challenges and provide effective, non-damaging cleaning while minimizing productivity irregularities caused by dust deposition.

The study evaluates the efficiency of solar panels with dust collected on them for various durations, such as one day, one week, and one month. The efficiency of the solar panels is also measured after cleaning the surface following each duration. By comparing the efficiencies before and after cleaning, it is evident that the

efficiency of the solar panels increases significantly. Thus, the developed model enhances the performance of solar panels.

Various sources of energy, such as coal, gas, hydro, nuclear, diesel, and even some renewable sources, are expected to be exhausted within a few years. Therefore, it is imperative to explore and utilize sustainable and renewable energy sources like solar power to meet our future energy needs.

Aim of the Project: This paper deals with an implementation of a solar panel cleaning robot which is used to efficiently and effectively clean solar panels to maximize their energy production and overall performance. Solar panels can accumulate dust, dirt, leaves, and other debris over time, which can reduce their efficiency and output. Cleaning the solar panels regularly helps maintain their optimal performance and ensures the highest possible energy output. The aim of the robot is to ensure the optimal performance and efficiency of solar panels while reducing maintenance costs and ensuring the safety of human workers.

Analysis of Dust on the Solar Panel: Research indicates that the daily energy loss over the period of a year, caused by dust deposition on the surface of PV modules, is approximately 4.5%. However, during extended periods without rain, the daily energy loss can exceed 20%. It is important to note that the irradiance loss is not uniform throughout the day and strongly relies on factors such as the sunlight incident angle and the ratio of diffuse to direct radiation. When analysed in relation to solar time, the irradiance loss exhibits symmetry with respect to noon, where it reaches its minimum value.

Various studies have examined the impact of different pollutants, such as red soil, ash, sand, calcium carbonate, and silica, on PV module performance. These studies have shown that the deposition of dust particles on PV modules leads to a reduction in voltage and output power, with the magnitude of the reduction dependent on the accumulated mass of dust and the specific type of pollutant.

Therefore, it is crucial to keep PV modules clean and cool to ensure efficient system performance. Regular cleaning and maintenance of solar panels are essential to minimize the negative effects of dust accumulation. Experimental testing can be conducted to determine the power generation of a solar panel with and without dust, considering varying load resistance, providing further insights into the impact of dust on the system's performance.

Need of the Project: Manually cleaning our solar panels will increase production temporarily, but the panels will get dirty again in a few weeks. Therefore, we have designed a project that automatically moves on the surface and clean the solar panel surface.

Some of the factors describes about the need of Project:

- **Increased Energy Production**
  Most of the people does not realize that our solar panels cannot generate full energy if they are dirty. So, by keeping the solar panels clean all the time, which can lead to an increased production of up to 25 percent energy.

- **Protect Panel Warranty**
  Some cleaning system harms the solar panels during the cleaning time by keeping solar panels clean is very important to maximize the energy production. Doing it in incorrect way that harms our panels and voided warranty. Our system cleans the solar panels in a correct way without harming the panels.

- **No personal Injury Risk**
  Climbing up and working on roofs of the solar panel is dangerous for people as well as panels.
  So, we designed a project that can clean the solar panel and eliminate the need of cleaners.

- **Completely Green**

  Our Project is completely green. We do not use any chemicals or products that harms our panels. It is also efficient with water utilization to avoid the unnecessary waste.

PV cells efficiency: The efficiency of PV cells (photovoltaic), also known as solar cells, refers to their ability to convert sunlight into usable electricity. PV cells efficiency is a crucial factor in determining the overall performance and economic viability of solar power systems. The higher the efficiency, the more electricity can be generated from a given amount of sunlight.

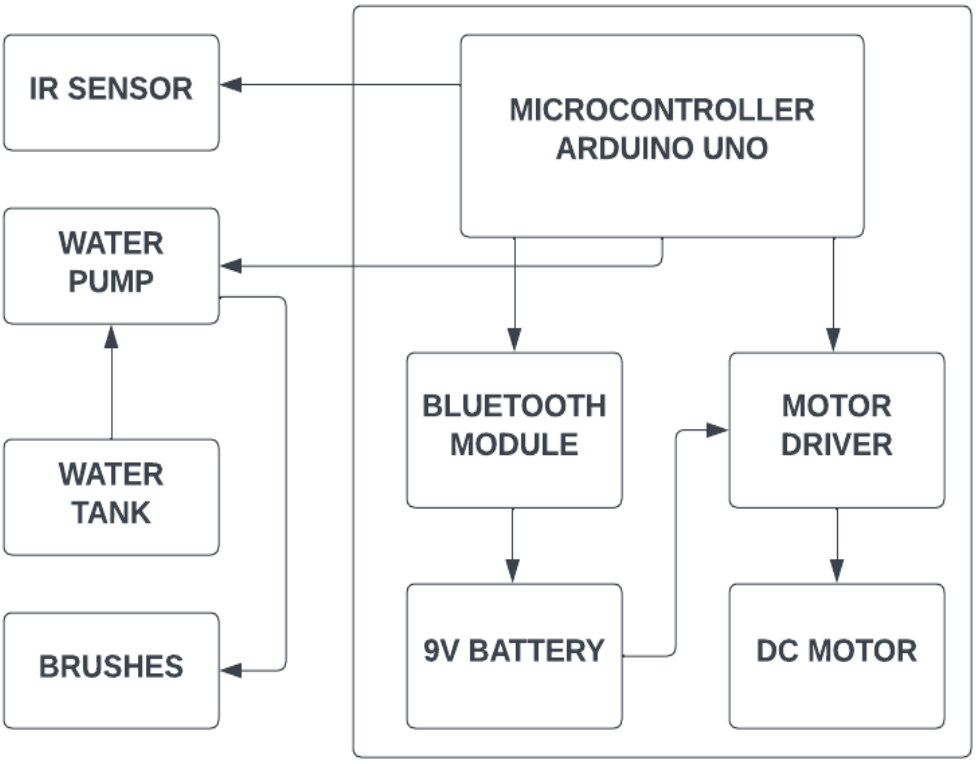
PV cell efficiency is typically expressed as a percentage, representing the ratio of the electrical power output of the cell to the power of the sunlight it receives. The efficiency of PV cells can vary depending on several factors, including the materials used, cell design, manufacturing processes, and environmental conditions. Monocrystalline silicon cells typically have higher efficiencies ranging from 15% to 22%, while polycrystalline silicon cells generally have efficiencies between 13% and 18%.

Components Used:

- Robot chassis,
- 5 DC motors (100 rpm)
- 1 12V DC Adapter
- 4 wheels (Gripped)
- 2 Rubber track belt
- 5 (IR sensors)
- Jumper Wires
- Bluetooth module

- Arduino UNO
- Water pump motor
- Pipe
- Water tank and Brush

Block Diagram:



Methodology:

Methodology of the Solar panel cleaning robot using Arduino and a Bluetooth:

1. Research and Planning:

- Familiarize yourself with the basics of Arduino programming and the components required for building a cleaning robot.

- Research different types of cleaning mechanisms suitable for solar panels.

- Understand how the Bluetooth module can be used to control the robot remotely.

2. Gather Components:

-Obtain an Arduino board (such as Arduino Uno or Arduino Mega) and a compatible Bluetooth module (such as HC-05 or HC-06).

-Collect other necessary components such as dc motors, wheels, a cleaning mechanism (brush or wiper), power supply, and sensors.

3. Design the Robot:

- Create a design for the robot's chassis that can accommodate the cleaning mechanism, motors, and wheels.

- Ensure that the robot's dimensions are suitable for maneuvering on solar panels.

4. Assemble the Hardware:

- Connect the motors to the Arduino board to enable movement.

- Connect the cleaning mechanism (brush or wiper) to the appropriate motor or a separate motor if required.

- Establish the necessary power supply connections.

5. Arduino Programming:

- Write the Arduino code to control the robot's movements and cleaning mechanism.

- Implement the Bluetooth module code to receive commands wirelessly.

- Define the logic for the cleaning mechanism's operation and how it interacts with the motors.

6. Testing and Debugging:

- Upload the code to the Arduino board and ensure that it functions as expected.

- Test the robot's movement and cleaning mechanism's operation.

- Use the Bluetooth module to send commands and verify if the robot responds correctly.

7. Refinement and Improvements:

- Analyse the performance of the robot and identify any areas for improvement.

- Fine-tune the code and make necessary adjustments to optimize the cleaning process.

- Consider adding additional features like obstacle detection or autonomous cleaning capabilities.

8. Documentation:

- Document the project, including the hardware setup, circuit diagrams, and the Arduino code.

- Take clear pictures or create diagrams to illustrate the construction and functioning of the robot.

- Write a step-by-step guide explaining how to build the robot and use it effectively.

Conclusion:

- A fully assembled solar panel cleaning robot has been developed. The control algorithm and cleaning sequence are established with the Arduino platform.
- The robot is designed to be fully powered by Li-ion rechargeable batteries. The experiment and verification results demonstrated the functionality of the cleaning robot to perform its duty.
- The solar photovoltaic output power is successfully restored to its maximum power capacity after the cleaning process. even though there are slight losses due to some glitch error in the system.
- The 50% improvement at the output current as well as the maximum power before and after cleaning reveals that the robot guarantees the effectiveness of the developed robot.

Future Scope: The technology that is being developed into this project to reduce the number of people required to clean the solar panels. We can clean the solar panels in night to improve the system and make it more efficient.

In future, we can develop a software in robot that when it cleans any solar surface, it will save the information about ledges, size, and its location. And, we can add flying mechanism into the robotic system that can fly from one solar panel to another. And adding auto-pilot system for the inspection, communication, and self-diagnosis**.**

Advantages of the SPCR Robot:

- Enhanced Efficiency: Solar panel cleaning robots are designed to clean solar panels quickly and efficiently. They can cover large areas of panels in a short amount of time, saving significant labour and operational costs.
- Cost Savings: Implementing a solar panel cleaning robot can lead to cost savings in the long run. While the initial investment may be higher than manual cleaning methods, the reduced labour costs and increased energy generation can result in a quick return on investment.
- Increased Safety: Cleaning solar panels manually often involves working at heights, which can be risky and time-consuming. Solar panel cleaning robots eliminate the need for human operators to work on rooftops or elevated structures, minimizing the risk of accidents and injuries.

- Improved Performance: Dust, dirt, and other debris can accumulate on solar panels over time, reducing their efficiency. Solar panel cleaning robots utilize advanced cleaning mechanisms, such as brushes, sprayers, or wipers, to remove these contaminants effectively.
- Environmental Benefits: Solar panel cleaning robots contribute to environmental sustainability. By maintaining the optimal performance of solar panels, these robots help increase the efficiency of renewable energy generation. This, in turn, reduces the reliance on fossil fuels and lowers carbon emissions.
- Remote Monitoring and Control: Many solar panel cleaning robots can be monitored and controlled remotely through computer systems or mobile applications. This feature allows operators to schedule cleaning cycles, track cleaning progress, and receive real-time performance data.

Disadvantages of the SPCR Robot:

- Initial Cost: The upfront cost of purchasing and implementing solar panel cleaning robots can be significant. The cost of the robot itself, along with any additional equipment and installation expenses, can make it a substantial investment, especially for small-scale solar installations.
- Complex Maintenance: While solar panel cleaning robots require minimal maintenance compared to manual cleaning methods, they still require regular upkeep and servicing. The maintenance and repair of the robot's mechanical and electrical components can be complex and may require specialized skills or technical support.
- Limited Adaptability: Although many solar panel cleaning robots are designed to be adaptable, some models may have limitations in terms of the types of solar panels they can clean or the configurations they can accommodate.
- Lack of Human Judgment: Solar panel cleaning robots operate based on pre-programmed instructions and algorithms. While this allows for consistency and efficiency, robots may lack the judgment and decision-making capabilities of a human operator.
- Potential for Damage: Although rare, there is a possibility of damage to the solar panels during the cleaning process, particularly if the robot's cleaning mechanism is too harsh or if the panels are fragile.
- Weather Conditions: Weather conditions such as rain, snow, or extreme temperatures can affect the operation of solar panel cleaning robots. Rainfall can potentially interfere with the cleaning process, and snow accumulation may hinder the robot's movement or cleaning effectiveness. Extreme temperatures can also impact the performance and durability of the robot's components.

Applications:

- Large-scale power plants,
- Commercial rooftops,
- Residential systems,
- Remote installations and
- Agricultural settings

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