Design and Performance of a Solar Panel Cleaning Robot

A thesis report submitted to the department of mechanical engineering for the partial fulfillment of the degree of Bachelor of Science in Mechanical Engineering.

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Declaration of Authorship

Bangladesh, hereby declare that the internship report titled **— Design and Performance of a Solar Panel Cleaning Robot** is prepared aster the completion of my internship at Design and Performance of a Solar Panel Cleaning Robot. We also declared that the internship report is prepared for an academic purpose and has not been submitted by me before of any degree.

We declare that the internship report embodies the result of own research work, perused under the supervision of **Md. Minhaz Uddin**, Assistant Professor, Department of Mechanical Engineering Sonargaon University (SU)

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Abstract

Solar energy, being one of the clean energy sources, plays a vital part in satisfying our planet's growing electrical energy demand. Many nations have created solar energy-based energy regulations in recent years, and academics have been working on solar panel efficiency, maximum energy extraction from the sun, control and power electronics. Solar panels transform the energy extracted from the sun into electrical power. Extraction of continuous maximum energy level from the sun decreases installation costs and allows meeting the required peak electrical power easier. Between the solar panel and the sun, physical circumstances such as muddy rain, snow, and dusting occur. This scenario leads to a lower amount of electrical power extraction than is physically possible with a clean solar panel surface. As a result, it is critical to maintain the solar panels and maximum power point tracking devices clean. A solar panel cleaning robot (SPCR) was created and tested in real time in this study. The developed crawler and dual-motor robot crawls horizontally, while the cleaning brush goes vertically. Furthermore, position switches can detect the length of the solar panel array to maintain the SPCR in the proper operating region.

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List of Symbols

°C	Degree Celsius
Cm	Centimeter
Gbps	Gigabits per second
Gm	Gram
K	Kilo
KB	Kilobyte
<	Less than
µA	Micro ampere
M	Mega
Mbps	Megabits per second
Mm	Millimeter
%	Percentage
$	US Dollar
V	Voltage

List of Acronyms

BI	Business intelligence
CAGR	compound annual growth rate
GDP	Gross Domestic Product
IDE	Integrated Development Environment
IoT	Internet of Things
IoWT	Internet of Wearable Things
4IR	Fourth industrial revolution
LAN	Local area network
LCD	Liquid crystal display
LTE-M	Long-Term Evolution for Machines
NB-IoT	Narrowband IoT
PLF	Precision Livestock Farming
SDK	Software development kit
Wi-Fi	Wireless Fidelity

Chapter 1

Introduction

1.1 Introduction

A photovoltaic panel is one that generates power from sunlight. A photovoltaic panel is made up of semiconductors that convert solar energy into direct current (DC). Because this technology is non-polluting, renewable, and safe, it has seen remarkable growth in recent years. Mega solar energy projects have already been built in numerous nations such as Australia, the Middle East, the United States, Europe, China, and so on. In the business sector, PV conversion efficiency ranges from 10 to 13%. However, the efficiency of outside installed PV modules may decrease by 10 to 25%. The decrease in efficacy was due to inverter, wiring, and dust pollution losses. Soil and dust particles (suspended dust), smoke, fog, and particulate matter known as dust are all examples of substances that disperse in the air. Dust is made up of inorganic and organic compounds found on Earth. Dust is made up of particles such as sandstorms, germs, factories, smoke, pollen, forest fires, and volcano gasses. They also contain suspended solid atmospheric particles that linger in the air for extended periods of time. These particles can travel considerable distances with wind motions. Areas with high dust concentration levels suffer large losses as a result of dust pollution. Many excellent researches have proven that airborne dust deposition on outdoor photovoltaic (PV) modules reduces cell glazing transparency.[1]

It also has a substantial impact on the solar conversion efficiency of PV modules. The accumulation of dust on the glazing transparency performance was the subject of outdoor PV experiments. Photovoltaic cells are commonly used in solar panels. (PV) cells with a protective glass layer that generates electricity when exposed to radiation a layer. The presence of dust on a PV module demonstrates its capacity to generate power. The mechanism is mostly made up of rollers. Brush for cleaning on a glassy surface with a slip-free action. A series of tests and outdoor testing were conducted Demonstrate the mechanism's effectiveness in cleaning the modules. Our project is likewise self-sufficient, and it is simple to use.[2]

1.2 Purpose of the Study

Many nations utilize various types of solar panel cleaning robots, such as the Solar Frames Connected Robot. The development of solar panel cleaning robots can be utilized to replace human labor, especially as they lower the danger of robot damage when moved and do not require a supervisor for working control. The Solar Frames Connected Robot still has a flaw, though, in that the size of the solar panel is restricted and it is difficult to move. By analyzing the movement of solar panel cleaning robots that are effective in Thailand, wireless joystick, sensor sonar employing gear motor, and ARDUINO microcontroller are used in this research to build and create the solar panel cleaning robots. In order to optimize the cleaning process, the robot will clean a solar cell utilizing a rotational brush and water spray. As a result of research on solar panel cleaning, gear motor-driven robots can move at temperatures between 0 and 30 degrees Celsius and use rotating brushes to clean 80% of solar panels.[3]

1.3 Statement of the Problem

Since the water utilized for washing the panels contains a highly soluble salt that harms the panels, PV modules determine the type of salt that deposits or adheres to the glass surface. The following washing of bird droppings makes this discoloration very obvious.[4]

1.4 State-of-the-art Solutions

An automated solar panel cleaning system protects your investment by keeping the solar panels clean all the time, which can lead to an increased production of up to 30 percent more energy. The brush which is attached to the cleaning robot takes away the dirt and dust from the panel. The robot is programmed with a microcontroller which controls its operations and its movement from one panel to the other panel.[5]

1.5 Objective

- To design a solar panel cleaning system which can increase the efficiency of solar panels.

- To using a water tank and water level indicator for cleaning with a spray water system and brush.
- To monitoring the working performance with a camera.
- To make the cleaning of solar panels simple and automated.
- To minimize human intervention.
- To cleaning system that does not affect the quality of the original solar panel.
- To environmentally friendly cleaning system.

1.6 Thesis Contribution

The accumulation of dust on the surface of a photovoltaic module decreases the radiation reaching the solar cell and causes loss in the generated voltage and power. Dust doesn't only reduce radiation on the solar cell, but also changes the dependence on the angle of incidence of such radiation. According to research, daily energy loss along a year caused by dust deposited on the surface of the PV module is around 4.4%. During long periods without rain, daily energy loss can be higher than 20%. In addition, the irradiance loss is not constant throughout the day and is strongly dependent on the sunlight incident angle and the ratio between diffuse and direct radiations. When studied as a function of solar time, the irradiance loss is symmetric with respect to noon, where they reach the minimum value. PV module performance has been tested under the deposition of different pollutants (red soil, ash, sand, calcium carbonate and silica). According to the obtained results, a drop of PV module's voltage and output power is observed when dust particles are deposited on the PV module depending on the mass accumulated and the type of pollutant. Moreover, larger reduction occurs when the PV module's temperature is increased. In addition to that, keeping the PV modules clean and cool, results inefficient system performance. Power generation in the solar panel with dust and without dust with varying load resistance is experimentally determined. [6]

Chapter 2

Literature Review

2.1 Introduction

Globally, there is more than enough solar radiation to meet the demand for solar power systems. The percentage of the sun's rays that reach the surface of the planet is sufficient to meet the world's energy needs 10,000 times over. On average, each square meter of land receives enough sunshine each year to generate 1,700 kWh of electricity. Our planet is greatly impacted by solar panels. Solar power plants need to be cleaned at least every three days, but it may benefit our environment by reducing the demand for other power producing facilities that might harm the environment. In general, it depends on the nation. For instance, in the Middle East, it must be cleaned daily, which adds to the expense. There are several methods for cleaning solar panels; our concept is to create a smart solar panel that cleans itself automatically and remotely in order to preserve the solar panel's high level of efficiency. [7]

2.2 Related Works

Solar Brush UAV Panel



Figure 2.1: Solar Brush UAV Panel

The amount of solar irradiance hitting the top of the panel determines how much electrical energy the photovoltaic cells can generate. Sun photovoltaic cells are put

outside to optimize their exposure to sun radiation. In an outdoor setting, dust begins to build up on photovoltaic panel surfaces, which limits the amount of solar radiation that actually reaches those surfaces. Similar to other bird droppings, ice, and salt deposits, these obstructions prevent solar irradiances from reaching photovoltaic panels.[8]

Photovoltaic cell cleaning methods are employed to address these problems. In-depth discussions of the various solar system cleaning techniques have been provided by Surajit et al. (2018). Autonomous cleaning robots have risen to prominence as one of the most effective solar panel cleaning solutions. Autonomous cleaning robots glide over the solar panel's surface and use gentle brushes to clean the panels without scratching their surface. The head is moved horizontally by motorized trolleys to which it is fastened. Typically, the belt-driven mechanism is in charge of controlling the head's vertical movement. Additionally, Grando et al. (2017) conducted research on several solar cleaning initiatives and technology. They have covered the operation of the Nomad cleaning systems, Ecoppia E4 wash panels, and solar brush UAV robot in their investigation. A drone called a solar brush robot cleans solar panels by gently rubbing its tail against the surface of the panel while flying extremely near to them. Since just a small portion of the robot is in direct touch with the panel, utilizing this kind of robot has several benefits. This considerably lowers the likelihood that the panel will sustain damage. [9]

Ecopia Solar Cleaning System



Figure 2.2 : Ecopia Solar Cleaning System

Ecopia's solar cleaning robot cleans the solar panel in a slightly different way. As seen in Figure 2.2, a guiding railing is connected above the solar panels in this design. The

horizontal movement of the guiding railing frame construction is possible over the array of panel surfaces. The robot moves on the railing frame for top-to-bottom movement. Ecopia solar panel cleaning project cleans the surface of the solar array by sweeping its microfiber brushes attached to the head. The system has a battery of its own, which is topped off by a solar cell of its own. This device's ability to store energy enables the system to clean the panels at night. Furthermore, internet-based control of the system is possible.[10]

Nomad Solar Cleaning System



Figure 2.3: Nomad Solar Cleaning System

Water and a horizontal brush are used in wash panel solar cleaning systems to clean the solar panel. A horizontal brush is fastened to the system's mobile assembly, as seen in Figure 2.3. This brush stays in close proximity to the panel. A brush rubs the panel's surface to remove any muck as the assembly of the system moves, and water splatters through water on the panels. The Ecopia system and the Nomad cleaning system are extremely similar. The sorts of brushes that rotate on the panel's surface are what differ most. A tiny truck carrying brushes travels through the array of the Ecopia system. The solar cleaning robot is moved by a number of pulleys and motors. In contrast to Ecopia system, nomad system. Only two motors—used to move the brush horizontally—are present. As seen in Figure 4, the railing where the brush roller often rests is behind the solar panels. The brush rotates in a circular motion around its axis while the assembly travels horizontally. The brush scrapes the panels' surface in a circular motion to get rid

of any debris and other obstructions. The system is entirely automated, intelligent, and capable of being set up for a variety of cleaning regimens. [11]

Support Vehicle Based Solar Panel Cleaning System



Figure 2.4: Support Vehicle Based Solar Panel Cleaning System

Figure 2.4 depicts another robotic solar panel cleaning system created by Sweezey et al. (2009) that uses a support truck in addition to the cleaning head and moving trolleys. The cleaning head scrubs the brushes on the panel's surface in a manner akin to the Ecopia and NOMAD systems. DC motors with a voltage of 12 volts are utilized to move the driving system. The top and lower trolleys may travel in various directions and locations. The device can clean the panels in a square wave pattern thanks to this capability.[12]

2.3 Summary

In this chapter, we present Design and performance analysis of a solar panel cleaning robot. And also discussed the Design and performance analysis of a solar panel cleaning robot technology.

Chapter 3

Methodology

3.1 Introduction

This section will introduce the components that make up the Design and performance analysis of a solar panel cleaning robot and discuss their working and features. But before the discussion above, let's take a look at the quality of semiconductor devices

3.2 Block Diagram

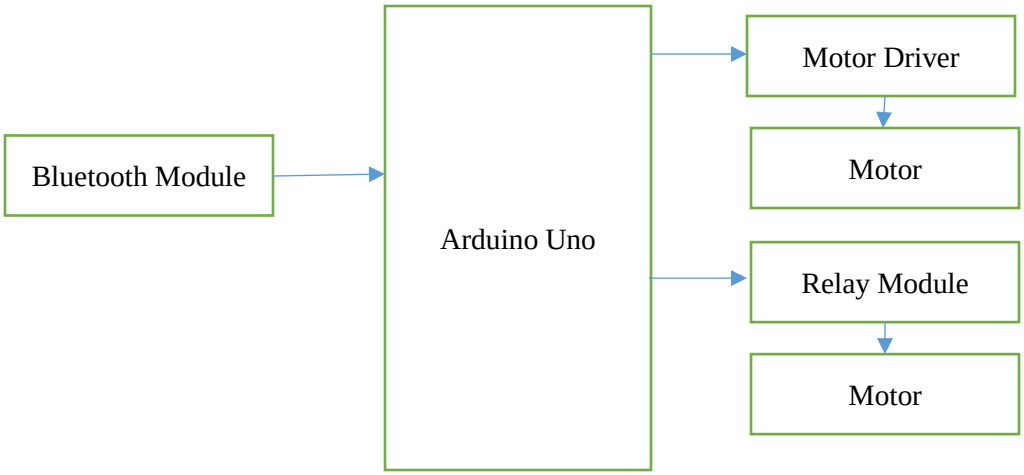


Figure 3.1: Block Diagram

3.3 Circuit Diagram

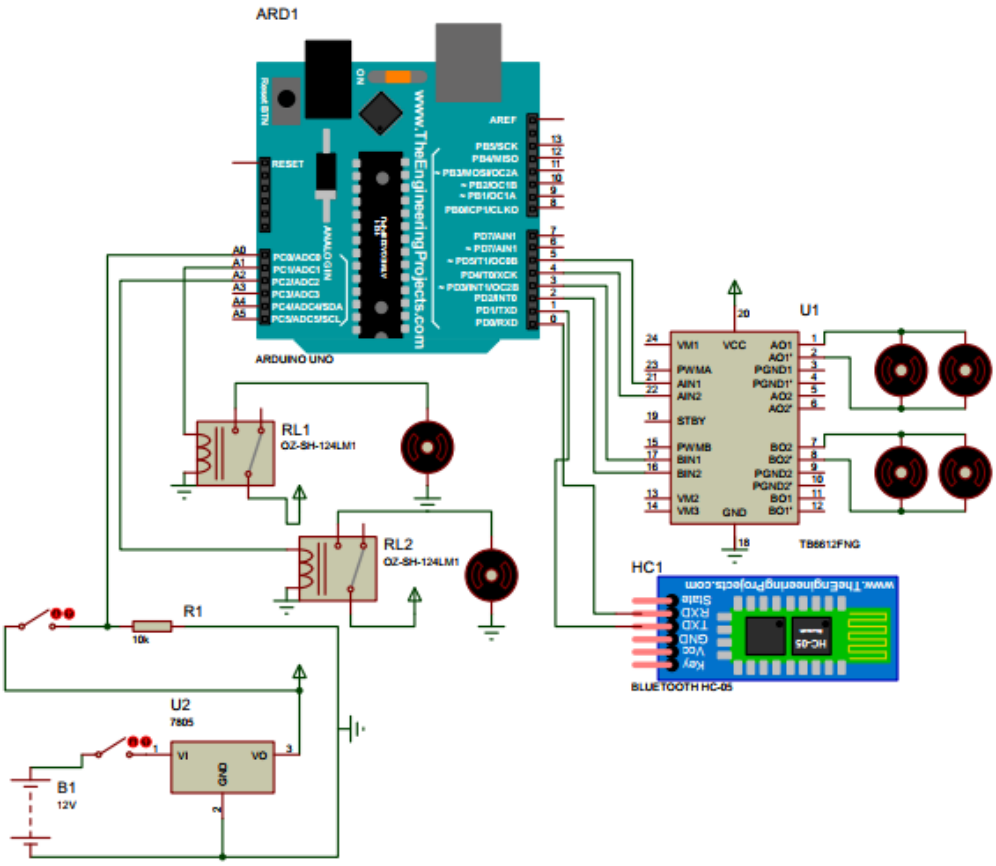


Figure 3.2: Circuit Diagram

3.4 Hardware Descriptions

The lists of components are:

- Arduino Uno
- HC 05
- Motor Driver
- Motor
- Battery
- Charger
- Wheel
- Hex
- Mount
- Water Pump
- Relay Module

3.5 Picture of the project

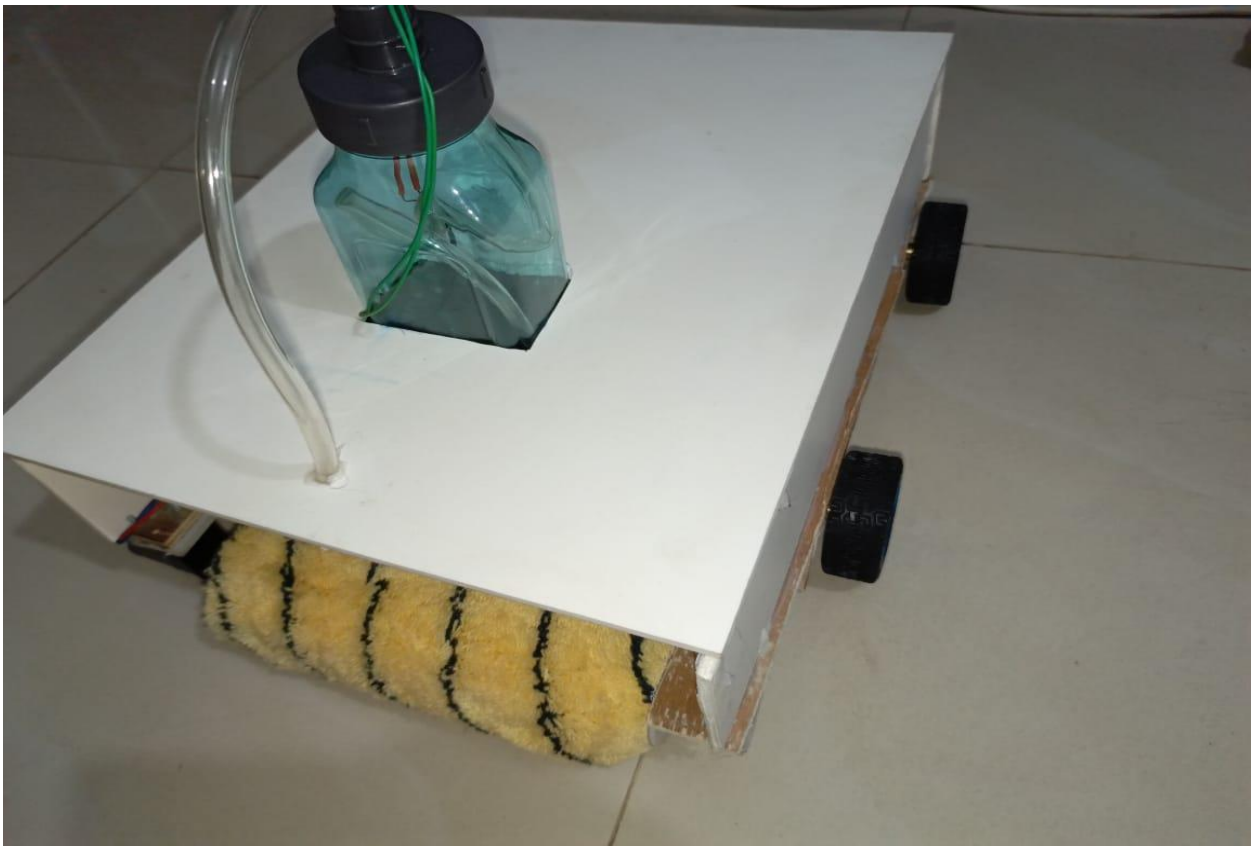


Figure 3.3: Photograph of Design and Performance Analysis of a solar panel cleaning robot.

3.5.1 Arduino Uno

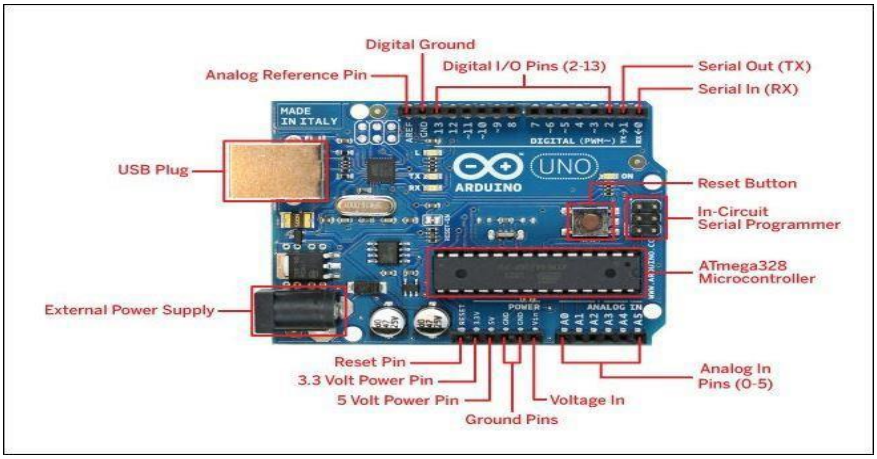


Figure 3.4: Arduino Uno

It is an Arduino-based microcontroller board founded on ATmega328P. The kit comes with all required to operate the microcontroller. All you have to do is link it to a computer using a USB cable and power it with an AC-DC adapter or a battery. The word "Uno" was preferred to signify the launch of the Arduino IDE 1.0 software. "Uno" is Italian for "one." The third and latest version of the Arduino Uno is called the R3. The reference versions of the Arduino board and IDE software are currently being updated. The main in a line of USB Arduino boards, the Uno-board obliges as the platform's reference design. The Arduino UNO microcontroller board is a programmable open-source microcontroller that can be integrated into a variety of electronic projects due to its low cost, flexibility, and ease of use. It can control relays, LEDs, servos, and motors, and it can be connected to other Arduino boards, Arduino shields, and Raspberry Pis. In the diagram below, you can see the pin diagram for Arduino Uno R3. There are 14 digits of I/O pins on it. A 6-pin connector can be used as a PWM output via these pins. Digital input/output pins are 14, analog inputs are 6, a USB connection is available, a quartz crystal clocks 16 MHz, there is a power jack, a USB connection, a resonator clocks 16 MHz, a power jack, an ICSP header is available, and there is an RST button.[13]

Arduino Uno features consist of the ensuing.

- The ATmega328P Microcontroller is from the 8-bit AVR domestic
- The working voltage is 5V
- Vin is 7V to 12V
- I/O pins are 22
- Analog i/p pins are 6 commencing A0 to A5
- Digital pins are 14
- Power ingestion is 19 mA
- It draws 40mA at the DC I/O pins
- Flash memory is 32 KB
- SRAM is 2 KB
- The EEPROM is 1 KB
- CLK speediness is 16 MHz
- Weight - 7g
- The size of the in-print circuit board is 18 X 45mm
- Provisions three kinds of infrastructures, for example, SPI, IIC, and USART.

3.5.2 HC 05

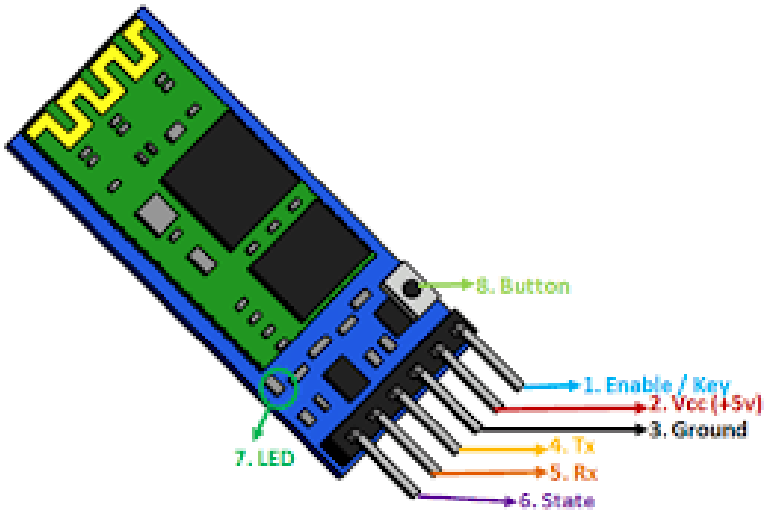


Figure 3.5: Bluetooth Module

A Bluetooth module (Bluetooth module) is a chip that integrates Bluetooth functionality, which is used to provide short-range 2.4G wireless communication. Bluetooth modules are semi-finished products as far as the end-user is concerned. A common Bluetooth module, the HC-05 is capable of adding two way (full-duplex) wireless capability.[13]

3.5.3 Motor Driver

Motor drivers serve as interfaces by connecting the control circuits and the motors. Motors need a lot of current, but controller circuits operate on signals with less current. Motor drivers are responsible for converting low-current control signals into higher-current signals that can drive a motor.[14]



Figure 3.6: Motor Driver

For motor driving applications, the BTS7960 is a fully integrated high current H bridge module. The integrated driver IC, which has logic level inputs, diagnostics with current sensing, slew rate adjustment, dead time generation, and protection against over temperature, overvoltage, under voltage, overcurrent, and short circuit, makes it simple to interface with a microcontroller. The BTS7960 offers a very space-efficient, cost-optimized solution for protected, high-current PWM motor drives.

3.5.4 Relay Module



Figure 3.7: A 5V Single channel relay module

A relay is an electrical operated expedient. An input circuit or input contactor may be referred to as a control system or controlled system for the device. It is habitually utilized in the spontaneous control circuit. The device uses a low-current signal to control a high-current circuit. Relays are automatic switches that are commonly used to control high currents with low current signals in automatic control circuits. An input voltage of 0 to 5V is needed for the relay signal. Using the Single Channel Relay Module, you can control high voltage, and high current loads such as motors, solenoids, lamps, and AC loads. Microcontrollers such as Arduino, PIC, etc can be interfaced with it.[15]

3.5.5 **Submersible DC Water Pump with 2m Pipe**



Figure 3.8: A 12V Submersible DC Water Pump with 2m Pipe

The maximum height of the water that may be raised by this pump is 1.5 meters. This pump functions well doesn't require any extra care, and also operates extremely smoothly. It operates on a 12V voltage and is soundproof. 500 liters of water can be pumped by it every hour.

3.5.6 LM2596



Figure 3.9: LM2596

With a voltage rating of 4.5-40V to 3-35V, it is an LM2596 DC-DC Buck Converter. Potentiometers are used to adjust the step-down power module.

Structures:

- Tuning process: Main, set the input voltage (usually between 4.5-50V),
- A positive input is IN+ and a negative input is IN-
- A positive output is OUT+, a negative output is OUT-
- Motionless power ingestion is simply 6mA.
- Linking: Fusing, plus the pin can be straight joined after the PCB.
- Short circuit fortification: current preventive, thermal security, self-recovery.
- Buck switching regulator (BUCK) that is not isolated.
- Short circuit protection: Current preventive, self-rescue
- It is possible to adjust potentiometers in either clockwise
- Non-synchronous rectify.

3.5.7 Lipo Battery 12 V 1100 maH

This is a kind of rechargeable battery that uses a polymer electrolyte instead of a liquid electrolyte, and is usually recognized as a lithium-ion polymer battery (LIP) or LiPo battery. High-conductivity gel-like polymer method this electrolyte. The specific energy of batteries like these is higher than that of other types of lithium batteries. This makes them ideal for applications for instance mobile expedients besides remote-controlled aircraft where weight is an important factor.[16]



Figure 3.10: Lipo battery

Battery electric vehicles are powered by lithium-ion cells in a sack setup. The number of small-capacity lithium-ion cells necessary to drive a vehicle can be increased by using a large number of them, however, various producers and research centers are considering huge lithium-ion cells with capabilities beyond 50 Ah. In a battery pack, more energy per cell would certainly decrease the number of cells and electrical connections, but a higher capacity per cell would pose greater dangers to the pack as a whole.

This type of battery is used by the Hyundai Motor Company in several of their hybrid means of transportation, along with by Kia Motors in their battery-electric Kia Soul. These batteries are also used in Boll ore, which is used in several cities for car-

sharing arrangements. In addition to small planes and gliders using self-sustaining motors, some larger gliders are also being developed using self-sustaining motors, such as the Schemp-Hirth Ventus-2.

3.6 Summary

In this chapter, block & circuit diagrams, hardware component lists, the camera, and the working process of are presented.

Chapter 4

Results & Discussion

4.1 Introduction

It is only possible to verify whether an item designed is useful after it has been used and the expected result has been obtained. It is imperative to check whether the Design and performance analysis of a solar panel cleaning robot circuit is working and achieving the desired correction. For this purpose, periodic monitoring of the desired outcome combined with the measurement of appropriate electrical parameters is necessary

4.2 Working Flow Chart

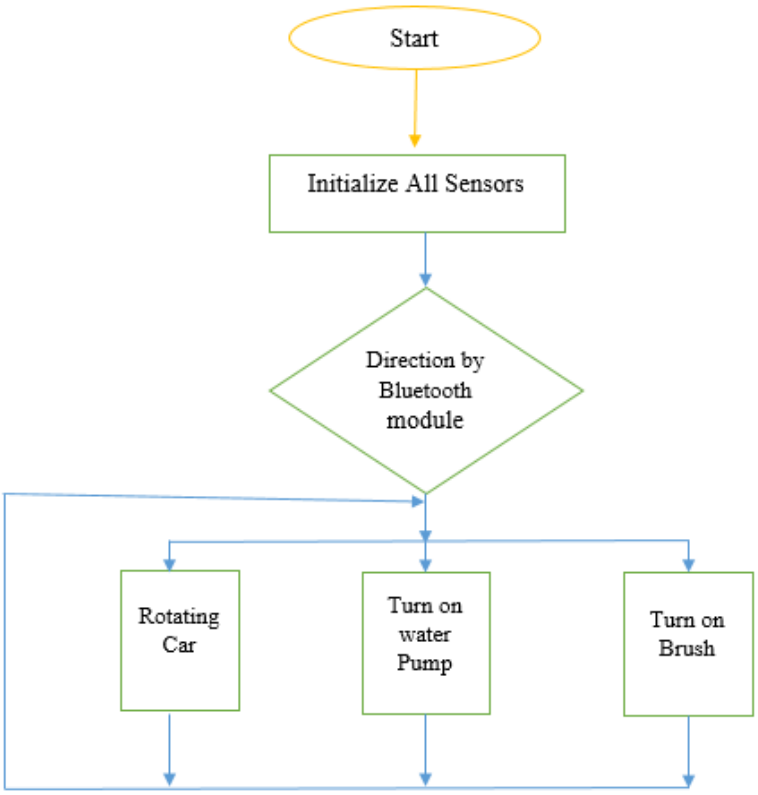


Figure 4.1: Working Flow Chart

4.3 Data Collection

a) Dust Type:

Solar panels may gather dust and debris from a variety of sources, including:

Fine dust and dirt particles that are transported by the wind and over time settle on the solar panels' surface are referred to as airborne dust.

Pollen: Tree, plant, and flower pollen can fall to solar panels and build up a thin layer of detritus.

Leaves and Debris: Depending on where the solar panels are placed, leaves, branches, and other organic debris may splatter and build up on the panels.

Bird droppings: When birds fly over solar panels, their droppings may have an effect on how effective the panels are. Air Pollution: Particulate matter and contaminants from automobiles and industry can condense on solar panels in metropolitan areas with high levels of air pollution.

Insects and Insect Droppings: On the panels, insects such as spiders and their webs may accumulate, as well as insect droppings.

Salt Buildup: In coastal regions, salt from the water can build up on the solar panels and perhaps affect how well they operate.

Rain and Water Stains: When rainwater evaporates, it can leave behind water stains on the panels by depositing debris and dust.

Mould and Algae: If solar panels are not cleaned frequently in humid or damp areas, mould or algae may develop on their surface.

Construction or other Activities: Solar panels may accumulate more dust as a result of construction work or other dust sources, such as dirt roads.

Over time, the buildup of this kind of dirt and debris can decrease the effectiveness of solar panels. It only takes a little coating of dirt to shade the solar cells and prevent sunlight from reaching them, reducing the amount of electricity the panels can produce. Solar panels must be cleaned and maintained regularly to work at their best. Some solar installations are made to some extent self-clean, but in many situations, human cleaning may be necessary, especially in places where there has been a lot of dust or debris buildup.

b) Simulation

We tried to clean horizontally the solar panel with 5 types of dirt, below gave its data table:

Table 4.1: 5 types of dirt removing time using robot

Dust Name	**10 gm**	**20 gm**	**30 gm**
Bird droppings	3 sec	5 sec	7 sec
Sand	2 sec	4 sec	6 sec
Leaves and Debris	2 sec	4 sec	5 sec
Salt Buildup	3 sec	6 sec	9 sec
Moulid and Algae	4 sec	7 sec	10 sec

After Next We tried to clean vertically the solar panel with 5 types of dirt, below gave its data table:

Table 4.2: 5 types of dirt removing time using robot

	Weight of Dust		
Dust Name	**10 gm**	**20 gm**	**30 gm**
Bird droppings	3 sec	5 sec	7 sec
Sand	2 sec	4 sec	6 sec
Leaves and Debris	2 sec	4 sec	5 sec
Salt Buildup	3 sec	6 sec	9 sec
Moulid and Algae	4 sec	7 sec	10 sec

c) Compares to our project

We can run the solar cleaning robot manually and automatically. Other papers show only manually operating the robot.

Our solar cleaning robot can carry 7-8 liter water tank. But in other papers it is shown that the water source is being piped separately.

With our robot, we can observe how much dust has been cleared with the help of a camera. And I can also see the water level.

4.4 Summary

In this chapter, hardware setup, the performance metrics, and the result analysis and discussion of Design and performance analysis of a solar panel cleaning robot are presented

Chapter 5

Conclusion

5.1 Introduction

This paper particularly presents a robotic system for autonomous cleaning of PV modules in a major way. Cleaning using basically such a robot basically has a lot of benefits over traditional method of ‘water wash’ cleaning in a particularly big way. It illustrates the comparison between these two approaches and depicts enormous really potential of employing a robotic cleaner, generally contrary to popular belief. In case of ‘water wash’, transporting water tanks in PV area results in emission of numerous gases creating air pollution in a pretty big way. However, mechatronic-based solutions reduce CO2 emissions and notably assist to preserve water and particularly fossil fuels for the future, which is rather significant. A low-cost prototype of the robotic cleaner was created and manufactured in-house, demonstrating how this study explicitly proposes a robotic system for autonomous cleaning of PV modules in a subtle way. The projected price of the prototype's primary components is listed below in a huge way. An operating scenario including the proposed robotic cleaner and PV modules is depicted in Fig in a significant way.It demonstrates that a very low-cost prototype of the robotic definitely cleaner has been indigenously built and produced, demonstrating how, contrary to common opinion, this research actually proposes a robotic system for autonomous cleaning of PV modules. Table I compares these two ways and highlights the great fairly potential of deploying a robotic cleaner, or so they believed. The roller brush scrapes the dust from the PV module, and then the blower fan blasts dust out of the module.

5.2 Concluding Remarks

Arduino Uno, motor, motor driver, wheel, hex, mount, relay module, Solar cleaning motor, water pump and esp32 cam IoT device are used for the subsequent conclusions were acquired:

This robot can run on its own and can be operated manually. Another thing about this robot is that this robot will carry water by itself, there is no need for water supply from

outside. The robot has a camera through which we can see how much the solar has been cleaned. We can also see the level of water in the water tank. Four ultrasonic sensors are installed around the robot due to which the robot will not wear out from the solar.

5.3 Practical Implications

Object identification and obstacle avoidance techniques are the main components of the autonomous, self-driving vehicles that automakers like Tesla and BMW have developed. Therefore, it may be applied to the creation of autonomous vehicles.

By automating operations in businesses, it is possible to do away with the need for dispatching and assembly workers, improving efficiency and lowering labor costs.

Robots may be utilized to investigate difficult places with incredibly small spaces since they are relatively small compared to people.

Exploring unsafe and toxic locations, such as gas storage facilities in plants, is required to maintain a safe working environment. Additionally, any problem, such as a release of dangerous gases, must be reported. Because human detection is risky, this is crucial.

It can be utilized in space exploration, which may entail examining the sorts of stuff on other planets, with additional development and investigation.

5.4 Limitations

Industrial and commercial because there are seldom water and energy sources close to the solar panels, solar panel cleaning systems are difficult to implement. Since they may be elevated or on roofs, carports, or other surfaces, cleaning them might be hazardous.

5.5 Future Scope

This idea has a lot of potential for modification, such as boosting its operation by employing surface vacuum cleaners and water spray.

- Sensors have the ability to change this. In this project, power supply was used for electric supply; however, this may be changed by utilizing a solar panel for power supply.

- Silicon brushes can be utilized in areas where cleaning effectiveness is maximized. A better and wider range of micro-controllers can take the place of Arduino programming.
- For essential cleaning tasks, it can also be operated via remote controls. Belt drives can take the place of a rack system.
- Even if our project was flawless and operating as intended, there are still many enhancements that may be performed to increase its cleaning efficacy.
- Sometimes, dust or other particles stay on a solar panel for an extended period of time, damaging the aluminum strip of the solar plate. Thus, this method helps us prevent these harms.
- Increases the output from your solar panels by up to 5 to 30%.

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