Design and development of waterless solar panel cleaning system

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Abstract. With around 300 clear and radiant days in a year, the determined sun-based vitality occurrence on India's property zone is around 5000 trillion kilowatt-hours (kWh) every year. The sunlight-based vitality accessible in a solitary year surpasses the conceivable vitality yield of the majority of the petroleum product vitality holds in India. The everyday normal sun-based power-plant age limit in India is 0.20 kWh per m² of utilized land territory. Efficiency of solar panels are poor when they are not clean. Water based manual cleaning is costly, brings about ecological damage. Apart from leading to an electrical hazard, water-based cleaning leaves deposits, and causes scratches because of scouring. With manual cleaning, there is a danger of harming the covering of the boards. Our design utilizes nylon bristled brushes making no harm to the panels. No weight or stress is applied on the photovoltaic cells. The cleaner robot is self-fuelled, and programmed. It navigates through the entire length and comes back to the docking position. This completes one work cycle. Cleaning is finished utilizing exceptionally planned brushes, lifting the residue far from the boards. The cleaner robot can be retrofitted to suit existing or customized solar panels.

1. Introduction

Solar Energy based power in our country, India is a rapidly expanding industry. The country’s solar power generation was 25.21 gigawatts on 31st December 2018. The nation’s government planned to achieve 20 gigawatts by the year 2022, but it was consummated 4 years before the deadline. In 2015 the goal for solar power generation limit was increased to about 100 gigawatts (including 40 gigawatts from rooftop solar power-based generation) by 2022, focusing on an investment of US$100 billion. India revised its goal for achieving solar power-based ceiling couple of times from 2650 megawatts on 26th May,2014 to 20 gigawatts by 31st January,2018. This country consisted of 3 gigawatts of solar-based ceiling in 2015-2016, 5 gigawatts in 2016-2017 and 10 gigawatts in 2017-2018, with the price of solar panels decreasing to about 18 percent, as compared to coal powered plants. Notwithstanding its huge scale network associated with solar power-based processes, the nation is developing off-lattice solar power for neighbourhood requirements.[6] Sunlight based components have extensively characterized and projected provincial requirements before the end of 2015, resulting in the sale of about 1 million units of solar powered lights across the nation, diminishing the need of lamp fuel. In 2015 around 118700 solar-based house lighting was introduced. In the year 2019 Indian Railways reported an arrangement for introduction of 4 gigawatts of solar panels along the tracks. The International Solar Alliance (ISA), an organizer which is headquartered in Tamil Nadu, India. The
state has fifth most elevated working sun-based power limit. The state has also achieved a limit of Rs. 3.47/unit.

The amount of area in the country is very less and per-capita land accessibility is also less. The devotion of area for establishing sunlight-based exhibits should contend with different requirements. Therefore, the use of solar panel cleaners is essential for increasing the yield and allowing proper usage.[1] The measure of area needed for solar-oriented power plants is around 250 sections of land for each 40-60 megawatt created. An option to utilize water zones like channels, lakes, repositories, ranch lakes and ocean for enormous solar power plants. These water areas can be used for cleaning solar-oriented boards. Thruways and railroads may likewise maintain a strategic distance from the land, which would reduce transmission-line cost. Solar-powered produced by road territories can used for charging Electric Vehicles, which decreases fuel cost. It is projected that solar panels will keep on reduction in their cost in order to contend with non-renewable energy sources.[3] Greenpeace recommends that India should adopt solar-oriented power as a predominant source for its sustainable energy requirements since it is densely populated country in the tropical region of the northern hemisphere with an enormous number of users. By increasing its sustainable assets by 2030, India can reduce its carbon footprint without bargaining its financial growth progress. The use of solar panel cleaners greatly affects the efficiency and therefore the new type of silicone brush reduces the impact on the panels. [2-3]

The Government of India is advancing towards solar-based projects. A report mentioned an allocation of 1000 Crores for the Jawaharlal Nehru National Solar Mission and perfect vitality support for 2010-2011 financial year, an extension to 380 Crores from past spending plan.[11] Monetary Allowance empowered private organizations to reduce there import obligation on panels by 5%. The expense of sunlight-based PV control in the World has tumbled to around 33% of its 2010 value, making sun based the least expensive option for sustainable power source and less expensive than control produced from petroleum products for example, coal and gas.[12-13] Government of India provides seventy percent and thirty percent sponsorship for establishment of housetop sunlight-based units. Extra motivators were also presented to housetop sun-oriented power plants from different state governments. In this way, expanding the quantity of sun-based boards would straightforwardly bring about introducing an appropriate cleaning component. Here are characterized framework will come into the picture, upsetting the whole business. [9-10]

2. Methodology of Project

Problem Definition: Functional design of this solar panel cleaning robot is carried out by considering it moving on edges of the solar panel, with the help of specially designed nylon wheels. These wheels are driven by two 12V motors of high torque. The roller brushes are used for this application where it is separately actuated by another 12V motor of low torque. The whole system is powered by a 12V DC power supply of 7Ah battery. Ultrasonic Sensors are used for determining the starting and ending position of the system and the signal is sent to the ARDUINO Mega board which is programmed in a way, to take necessary action.

Objective: The requirement of this prototype is to increase productivity of the solar panel by cleaning the dust present on its surface. This project has the ability to reduce the cost of manual labour. It can help in reducing the cleaning time of the solar panels. It also promises in saving a large amount of water resource because it is a waterless system.

Project Design and Implementation: The mechanical design of the system was created using SolidWorks software. The Frame of the system is made using Aluminium 6063, where we cut the aluminium frame using the cutting power tool. The dimensions of the frame are 516 x 104 mm. The Wheels have been made up of Nylon, this material was cut to a diameter of 70mm. Using CNC machines and lathe machine it was given proper dimensions. Motor Coupler is made up of Aluminium and it was cut to diameter 60 mm using CNC machines and proper dimensioning with holes was given using drill tool. Motor Mounts is made up of Aluminium, using the power tool a L bent was cut. With proper marking of 12mm and 3mm holes were made for proper mounting of the motor. 3mm Bolts
were used for mounting the motor on it. Brushes are made up of Nylon with smooth Nylon bristles. Ultrasonic Mounts was made of using sheet metal aluminium with 100 x 75mm dimensions. The components were accumulated and the final assembly of the mechanical components was completed. First the motor was coupled with the motor mount. Then this sub assembly was connected with the wheels using motor coupler. This entire wheel assembly was then connected to the main frame with the help of bolts and nuts. Then similarly the brushes were connected with its motor using the motor coupler. This was mounted on the main frame using the motor mounts.

![Figure 1. Assembled robot front view.](image)

![Figure 2. Assembled robot side view.](image)

The above presented figure 1 and 2 depict the Assembled robot front and side view with complete mechanical fabrication and placement of motors and nylon brushes and wheels.
The electrical motors were chosen of about 12V with 22kg-cm torque value along with a 12V
2kg-cm motor. Motor drivers were selected based on the compatibility of the motors with it.
Ultrasonic sensors were selected because of its high accuracy. It does not get affected by dust, dirt, etc.
Our sensor selection was totally based upon our requirements. There are a lot of constraints in Infrared Sensors, similar to the powerlessness to use them in daylight due to obstruction. It can make open-air applications or dull indoor activities extremely cumbersome. Ultrasonic Sensors work utilizing sound waves, recognizing impediments isn't influenced by the same number of variables. As unwavering quality is a significant factor in our sensor choice, Ultrasonic Sensors are more dependable than Infrared Sensors.[7]

| Table 1. Mechanical Components and Specifications. |
| Sr No. | Components      | Specification            |
|--------|-----------------|--------------------------|
| 1      | Frame           | Aluminium 6063O 516*104mm|
| 2      | Wheels          | Nylon dia.70mm           |
| 3      | Motor Coupler   | Aluminium dia.60mm and 40mm|
| 4      | Motor Mounts    | Aluminium                |
| 5      | Brush           | Nylon OD= 101.6mm ID=20mm Length= 516mm |
| 6      | Ultrasonic Mounts | Aluminium 100*75*1mm    |

| Table 2. Electrical Components and Specifications. |
| Sr No. | Components       | Specification            |
|--------|------------------|--------------------------|
| 1      | Ultrasonic Sensor (2) | HC SR04, Minimum dist.=3cm |
| 2      | Arduino Mega 2560 | 54 digital i/o pins,16 analog pins |
| 3      | Dual Dc motor driver | 12V,20A                      |
| 4      | L298 Motor driver | 12V,2A                          |
| 5      | DC motor (2)     | 12V,200rpm,22.5kg-cm torque, load current upto 7.5amp(max) |
| 6      | DC motor (2)     | 12V,2amp(max)              |
| 7      | Battery          | 12V,7Amp hr.               |
| 8      | Breadboard       |                          |
| 9      | Jumper wire      |                          |

The above-mentioned Table 1 and 2 demonstrates the mechanical and electrical components along with their specifications.

3. Control Structure
As Figure 3 illustrates the working of the system. Let Ultrasonic sensor1 be the front sensor giving the output as D1 which is the distance between the sensor and the solar panel, similarly distance D2 which is calculated with the help of ultrasonic sensor2 which is the back sensor and both these sensors help the bot to avoid falling down of the solar panel. The distance D1 and D2 is calculated by the with the help of microcontroller Arduino mega 2560 which when coded gives the logic for both the H bridge motor driver to operate and also help in change the direction of rotation of the motor. Power supply that is 12V for the motors is fed through the motor driver by means of Battery. L298 motor driver is responsible for powering the motors in brush and using Arduino mega 2560 by connecting the 5V of
the motor driver to the Vin pin of the Arduino. Motor 1 and 2 are motors meant for brushes and is connected to L298 motor driver and motor 3 and 4 are meant for wheels and is connected to Dual DC Motor driver.

Figure 3. Block Diagram of Electronic Components.

Figure 4. Flow Chart of Uploaded Code.

Figure 4 depicts the operation performed by the uploaded code in Arduino Mega. The program starts with a trigger pulse from ultrasonic sensors which define a variable for forward or backward motion of the motor. It initiates mode of 3 pins of the motor. It creates a dis function for calculating distance. If the value is greater than the threshold value then it will command the motor to move in forward direction or else to move in backward direction.
As Figure 5 demonstrates that the system was completely assembled by placing all electrical and electronic components in place. Circuit connections were done using wires and jumpers. The sensors and motor drivers were placed on the mount and frame respectively.

![Figure 5. Complete Assembly of the Cleaning System.](image)

4. **Future Scope of the project**
The system that we have made is a working prototype which demonstrates our mechanical design along with its durability and feasibility. Further future study in this project might involve using dust sensors which would be calibrated to a certain threshold value such that it will automatically start the system without any manual on and off switch. Further inclusion of Bluetooth module can enable the users to switch on the system from a certain safe distance. The results of the cleaning can be uploaded in a cloud server where it can be monitored and certain commands can be given in order for proper functioning of the system.

5. **Conclusion**
The assembly of the system was carried out efficiently and precision was given utmost importance. We ran the code and an inference was drawn from the results. The code ran perfectly without any error. The mechanical system responded to the code and the ultrasonic sensors that were used, provided good response time. The ultrasonic sensors were calibrated to about 4 cm from the solar panel board. As soon as the value was greater than the threshold value the robot was traversing across the solar panel. Our hypothesis was that the system will respond to the code and after successful testing sessions we can say that our results do validate our hypothesis. In our opinion the tests went without any difficulties and we experienced no problems, except for the fact that we had to adjust the wheels accordingly in order to prevent less friction and efficient and synchronous movement of the system.

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