International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 11 | Nov 2020 www.irjet.net p-ISSN: 2395-0072

Design of Robotic Cleaning System for Industrial Solar Panel Arrays

Sachin Mathew[1], Maria Susan Abraham[2], Jishnu KS[3] and Amina A[4]

[1-4]*Dept. of Electrical Engineering, College of Engineering, Chengannur, Kerala, India*

Abstract - *With growing costs of electricity and concern for the environmental impact of fossil fuels, implementation of eco-friendly energy sources like solar power are rising. The main method for harnessing solar power is with arrays made up of solar panels. Accumulation of dust and debris on even one panel reduces their efficiency in energy generation considerably and emphasizes the need to keep the panels' surface as clean as possible. Current labour-based cleaning methods for solar arrays are costly in time, water and energy usage and lack automation capabilities. In this project a novel design is presented for the first ever human portable robotic cleaning system for solar panels, which can clean and maneuver on the glass surface of a Solar panel array at varying angles from horizontal to vertical. This is done with The help of Microcontroller board Arduino Uno which easily controls all the devices used in this particular model and therefore helps us to understand the required parameters which deal with the change in efficiency brought about by the cleansing of the solar panel arrays.*

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

1. INTRODUCTION

Nowadays, energy related aspects are becoming extremely important. They involve, for instance, a rational use of resources, the environmental impact related to the pollutant emission and the consumption of non-renewable resources. Most of the industrial applications use the solar panel as an electrical power source instead of relying on the generators or ordinary source of electricity. For these reasons, there is an increasing worldwide interest in sustainable energy production and energy saving. Growing interest in renewable energy has led the solar photovoltaic (PV) industry to expand notably in the last decade. There is an urgency in improving the efficiency of solar power generation. In order for the photovoltaic cells to operate at optimum efficiency without any loss of energy (zero energy loss), the surface of panel need to be dust free and in absence of any kind of particle which obstructs the flow of photons. Thus, efficiency drops quickly with solar panel contamination, since any dirt or obstruction on the way between the sun and the solar cells blocks sunlight and reduce collected energy.

The main factor that affects a PV panel's efficiency is dust, which can reduce its efficiency by up to 25%to30%, depending on the environment. A photovoltaic (PV) module can accumulate 80–300 mg.sq meters of dust per day, and every 100 mg.sq meters of dust accumulation causes an additional output loss of 0.4%to0.7%. After being exposed to ambient dust for one month, the soiled PV module will typically be able to produce 85% of the electricity it could if it was clean. Annual losses caused by this trend due to soiling ranges from 1.5% to6.2% depending on the location of the PV plant. After a slight rain, the efficiency of some PV panels declined sharply, whereas the performance of other panels was improved. At least 20 mm of rainfall is needed to clean the surface of PV systems, otherwise the systems will continue to experience power loss due to the dust and soil. Though the bird dropping and dirt is not making a big issue, it can be seen that the efficiency of solar panel decreases by 15%to20%. Therefore, cleaning the solar panel in a frequent period is necessary for getting same output for longer time.

A systematic and effective robotic device can clean large scale parks with low water utilization when compared to intervention of manual cleaning and present mechanical substitutes. We need to use water for the cleansing process because it helps in improving the efficiency as it is known that most of the commercial crystalline silicon photovoltaic cells observe a suitable current voltage characteristic at lower temperatures. This relates to the use of water by the bot to be sprayed on the photovoltaic cells which improves its efficiency by more than 15%. Automation is essentially required with this process since it has a better perspective in both utilization as well as brings about better handling by human and reduces manual inspection, hence there is a chance of cleaning system with auto lining features. Extremely important advantage of an automated robotized answer for the question raised about the cleaning of solar panels is the robustness, thoroughness, test-retest reliability and optimized speed of cleaning with which the controlled process works in comparison to traditional methods.

2. LITERATURE SURVEY

In this paper you will find the idea of how the system will help you to clean the solar panels without the help of human. To do so various different kinds of research paper has been reviewed so that the concept should be clear and the manufacturing of system should be easy. The need to clean the solar panels on regular basis is necessary because accumulation of dust on panels reduces the intensity of incident rays, thus reducing its production efficiency. So periodic cleaning of panels is necessary either manual or by automatic. With reference to these papers we have developed

A new and easy technique to clean the panels. Various different methods are there for cleaning of panels like human using brush, spraying of water. But with the use of such

techniques we are wasting water as well as we are investing huge amount in cleaning. They have designed a robot which is human operated and thus it cannot work all the time as the panels should be cleaned after specific interval of time. Hence there should be some automation done for better scope.

So, design of new system is necessary so that there will not be any complexity in use and it will be fully automatic. Cleaning the solar panels is normally by washing which is very tedious and cumbersome, at the same time its expensive too. The design of automatic cleaning robot will have flexibility in order to fix on different sizes of flat solar panels. There is need of improvement in these conventional methods. An alternative to all these methods is to be found. There is a need to achieve maximum efficiency by keeping the panels clean so that the rays can penetrate maximum amount of it on panels.

3. METHODOLOGY

Automated solar panel cleaning bot is a cleansing device used for cleaning the solar panels with minimal amount of water usage. The bot designed is composed of a cleaning head which will effectively clean dust and debris on the surface of the solar panel. Wheels and track belts are used for the movement of automated solar panel cleaning bot over the surface of the solar panel arrays to reduce the risk of scratching the glass surface of the solar panel. It operates on a 12V lead acid battery that provides three hours of usable time per full charge. The bot can also change its direction to movement when it reaches the edge of the solar PV array. The bot can clean at an inclination of 40 degrees.

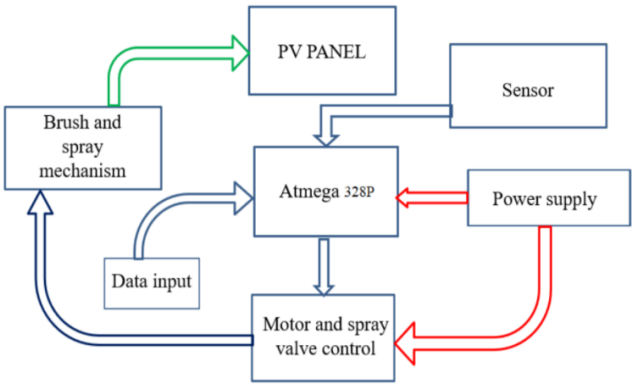

Fig -1: Basic Block Diagram

4. COMPONENTS

4.1 Microcontroller

ATMEGA328P is the microcontroller used in this project. It is a high performance, low power controller from Microchip. It is an 8-bit microcontroller and basically an Advanced Virtual RISC (AVR) microcontroller. It supports the data up to eight (8) bits. Atmega328P has 32KB internal built in memory. This microcontroller has a lot of other characteristics such as 1KB Electrically Erasable Programmable Read Only Memory (EEPROM). Atmega328P has 2KB Static Random-Access Memory (SRAM). These features consist of good performance, low power consumption, real timer counter having separate oscillator, 6 PWM pins, programmable Serial USART, programming lock for software security. It operates ranging from 3.3V to 5.5V.

4.2 Lead Acid Battery

Lead acid battery of 12V and 7Ah is used in this project. Lead acid batteries are composed of a lead-dioxide cathode, a sponge metallic lead anode and a sulphuric acid solution electrolyte. The cell voltage is 2V. The depth of discharge in conjunction with the battery capacity is a fundamental parameter in the design of a battery bank for a PV system, as the energy which can be extracted from the battery is found by multiplying the battery capacity by the depth of discharge.

4.3 DC Motor

(i) For movement of wheels

A 12V 300 RPM DC motor is used for the movement of bot. 300RPM Series DC Motor is high-quality low-cost DC geared motor. It has steel gears and pinions to ensure longer life and better wear and tear properties.

(ii) For movement of brush

A 12V 500 RPM DC motor is used for the movement of brush. The motor has sturdy construction. The shaft uses metal bushes for long life. It comes with High-Quality gears. The shaft also has a hole for better coupling.

4.4 Motor Driver

RKI 1004 is the motor driver used in this project. It's an H bridge motor drive. An H bridge is an electronic circuit that switches the polarity of a voltage applied to a load. These circuits are often used in robotics and other applications to allow DC motors to run forwards or backwards.

4.5 Ultra Sonic Sensor

HC-SR04 is the ultrasonic sensor used in this project. HC-SR04 Ultrasonic sensor is a 4-pin module, whose pin names are Vcc, Trigger, Echo and Ground respectively. This sensor is a very popular sensor used in many applications where measuring distance or sensing objects are required. The module has two eyes like projects in the front which forms the Ultrasonic transmitter and Receiver. The sensor works with the formula that

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

The Ultrasonic transmitter transmits an ultrasonic wave, this wave travels in air and when it gets obstructed by any material it gets reflected back toward the sensor this reflected wave is observed by the Ultrasonic sensor.

4.6 Water Pump

Water pump is used to spray the water to the PV panel through nozzle while cleaning the panel. A 12V DC 100PSI Pressure diaphragm water pump is used here.

4.7 Wheels and Track Belt

Wheels of 6cm diameter in used in this project. Four wheels are attached to both sides of the frame so as to give better movement to the embodiment. Track belt is made up of rubber is used to avoid the slipping and also to hold the wheel in a position.

4.8 LCD Display

A liquid crystal display (LCD) is a flat panel display or other electronically modulated optical device that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome.

4.9 Switch Keypad

The 16-button keypad provides a useful human interface component for microcontroller projects. There is convenient adhesive backing to provide a simple way to mount the keypad in a variety of applications. It is an ultra-thin design and has excellent performance ratio. It is very easy to interface to any microcontroller.

4.10 Nozzle

Nozzle is used to spray water. A nozzle is a device designed to control the direction or characteristics of a fluid flow (specially to increase velocity) as it exits (or enters) an enclosed chamber or pipe.

5. DESIGN

5.1 Design of Frame

Metallic sheet of 2.44x1.22x1 mm is used to make the frame of the bot. The standard size of industrial solar panel is 77x39 inches (195.58 cm x 99.06 cm). So, the size of frame is designed to have a length of 50cm and width of 35cm in order to balance the weight and efficiency. So, the bot can effectively clean the entire size of the panel. If the bot is too heavy, then the efficiency decreases and if the size is decreased, the cleaning time increases. So, this is the most suitable size for the bot, and it can be used for panels of all sizes.

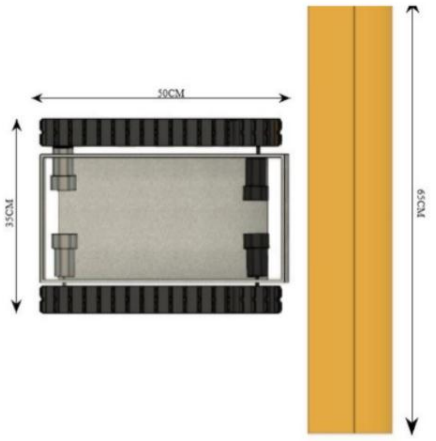

Fig -2: Design of Frame

5.2 3D Model

The 3D model of the automated solar panel cleaning robot is drawn on fusion 360. The cleaning robot consists of the frame which supports the entire system of the bot. The frame consists of head which has brush which is used to clean the surface of the panel. The motor and the other equipment's of the bot are placed inside the structure of the frame.

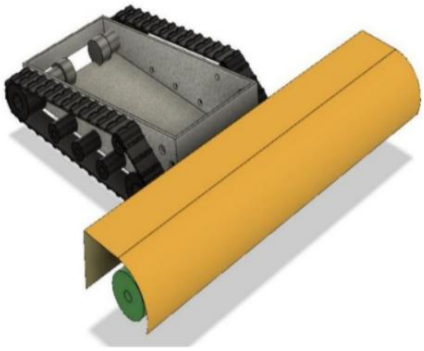

Fig -3: Top Side View

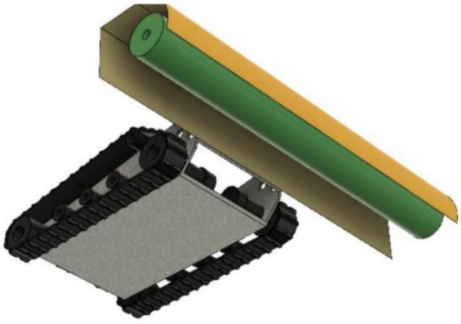

Fig -4: Bottom Side View

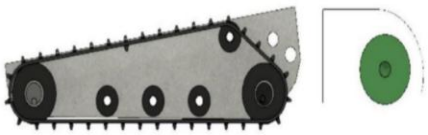

Fig -5: Side View

5.3 Software Development

The new software is programmed to follow a path on the surface of PV panels from one edge to other edge in order to minimize the cleaning time and power consumed. The robot's path was chosen to be vertical to make the robot more stable. If the path is set to be horizontal some force from the side will push the robot down. When the robot detects the end of the panel it will change its direction of movement. It will be either on the top right side of the panel or on the bottom right side when it is finished. The robot then stops and wait to restart to do the next run of cleaning.

5.3.1 Motor - Arduino Interfacing

The initial step of software development is the interfacing of motor and the Atmega328P. It is done with the help of RK1 1004, the motor driver. The DC motor speed can be controlled by applying varying DC voltage, whereas the direction of rotation of the motor can be changed by reversing the direction of current through it. For applying varying voltage, we can make use of PWM technique. For reversing the current, we can make use of H-bridge circuit or motor driver ICs that employ the H-bridge technique.

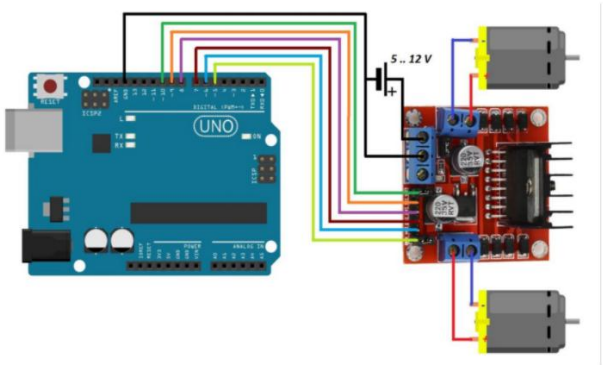

Fig -6: Motor – Arduino Interfacing

5.3.2 Switch Keypad – LCD Display – Arduino Interfacing

The next stage of software development is interfacing the LCD display and switch keypad with the Atmega 328P. This is done in order to enter the length and breadth of the solar panel to be cleaned. Switch keypad is used to enter the length and breadth of the panel which is then displayed on the LCD display. The switch keypad, LCD display and Atmega328P is interfaced using c programming.

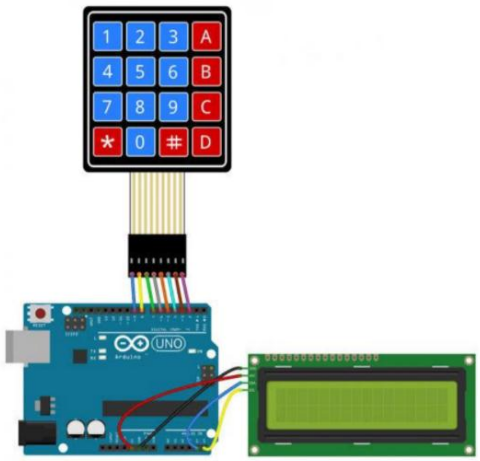

Fig -7: Switch Keypad – LCD Display - Arduino Interfacing

5.4 Hardware Development

The The Bot for cleaning of panel designed in this case is composed of a cleaning head that moves across the panels with the help of stainless steel rod using a track belts. This design was selected because of its less cost involvement, simplicity and robustness. The risk of scratching the glass Surface leads to the movement with the help of wheels and manual force. The test-retest ability of this design allows acceptable continuous functionality on a wide range of array dimensions. Although not all panels or arrays are of the same size, but the system is adaptable due to its ideal size. The panel columns have continuous travel since the robot can cross the side edges between the panel frames.

The chassis of this robot is made up of Aluminium Material. It consists of 4 L-Shaped motor mountings to hold Motors on their proper position. Chassis also provides rugged structure for battery and another electronic component. The nylon brushes are hollow cylinders of length 160mm with outer diameter of 75 mm and inner diameter of 11.8 mm weighing 120 g. These brushes have nylon filaments. Three brushes are used and held together. The Brushes are tightly packed so as to give a good deburring application. The brushes are rotated with the help of DC geared motor which gives a torque of 10 kgcm. Motor needs battery of 12V to operate at its optimum capacity. The motor is held in place using mounting. Along with rubbing the dirty surface, we also need to wash it sometimes with high pressure water pointed at the surface in a particular pattern. This is achieved with the help of nozzle.

5.5 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

6. WORKING

With the help of components and by assembling them, a wireless cleaning robot is made. 12V battery gives power supply to run motors. Track belt is located over wheels of robot. These wheels are attached with motors and receive power from it. With this, robot can propagate over solar panel surface. For the cleaning process to start, the length and breadth of the solar panel to be cleaned is entered through the keyboard and it is displayed on the LCD screen. Once the length and breadth are entered, then the motor starts moving and the wheels moves forward. As the motor starts, the spraying and the cleaning mechanism also starts. The bot moves forward and cleans the surface of the solar panel. When the bot reaches the end of the panel, the ultrasonic sensor detects the edge of the edge of the panel and stops the motor. Then the bot changes its direction by operating one pair of motors at a time. Once the direction is changed, the bot continues the cleaning process and moves forward further. The process continues and the entire surface of solar panel is cleaned. The bot operates from the 12V lead acid battery and water is sprayed with help of nozzle and water pump.

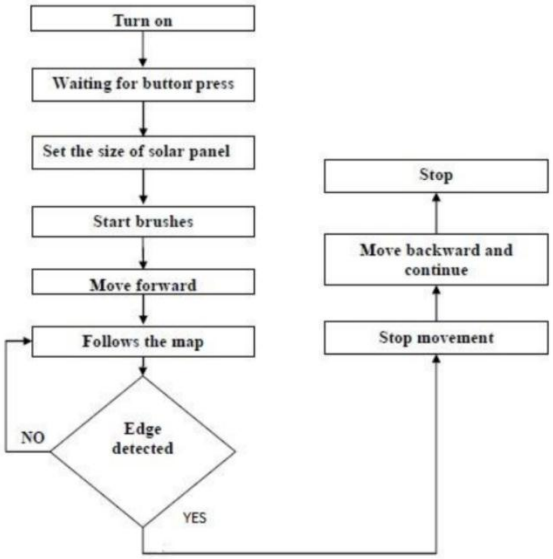

Fig -8: Flowchart

The bot is made to move in a zigzag manner. The bot follows the path so that it can cover entire surface of the panel. The program has these considerations:

1. The bot follows the sequence path as shown in figure.
2. By using ultrasonic sensors, the edges of the PVs are recorded so that it does not fall off.
3. Stops the motor after finishing the cleaning process.

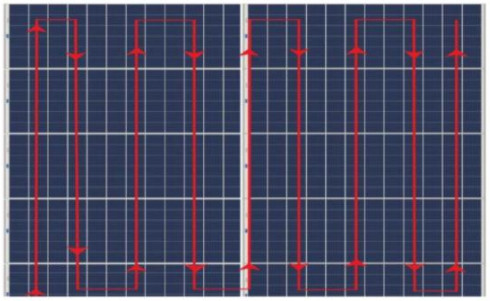

Fig -9: Moving Path of the robot

The table demonstrates the direction and movement of the robot when the ultrasonic sensor detects the edge of panel. There are possible ways to change the robot's direction.

• Initially, when the sensor is low, the robot will travel straight.

• The second way, when the sensor detects an edge, the sensor becomes high. The robot will stop then moves backward a certain distance, then turn to the right side 180o and move forward a certain distance straight.

• Then the robot will turn to the right side 180o and will travel straight until the ultrasonic sensor turns high.

• The movement continues until the lower edge of the panel. The sensor goes high and the robot will stop and moves backward a certain distance, then turn left 180o and then move a certain distance straight.

• Then the robot will turn left again an angle of 180o, then the process continues.

• The process ends until the described path is completed by the robot.

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

7. RESULT

The result of the bot is the efficient cleaning of the solar panel to remove the dirt and dust accumulated over the surface of the panel. The bots can reduce the cleaning cost by 80% compared to manual cleaning. Cleaning the solar panel to remove the dust particles and debris increases the efficiency of the solar panel by about 25%. It reduces the water consumption by 90% for removing the dust. It can fit to almost every panel size across the globe.

(i)Reduction in manpower:

Robot requires less time for cleaning of solar panel in comparison with manual cleaning. It ultimately reduces total time required for cleaning of all panels.

(ii)Efficient cleaning:

As we studied there are many problems in manual cleaning such as it is unable to clean sticky dust and materials present over surface. This cleaning robot removes those sticky dust and materials.

(iii)Increase in Power generation:

This robot gives a cleaned surface after operation in easy way and in less time and effort. As we know, due to dust deposition sun rays cannot reach the surface. On cleaned surface, sunrays impartation increase. So efficiency of panels increases by about 25%.

(iv)Reduction in water consumption:

Existing cleaning mechanism consumes more water for cleaning. In this proposed system water consumption can be controlled by nozzle and valve.

(v)Fit to every panel:

This portable device is fit to all panel. We can clean almost every panel size with this robot.

(vi)Reduction in cost per area:

Since it can cover the large area per charge with less water consumption it reduces the cleaning cost by 80%.

8. CONCLUSION

The deposition of any kind of biological and chemical dusts on the panel affects the PV performances, hence decrease the solar PV output power. By cleaning the high density of dust deposition the PV performance can be increased again. Thus cleaning and maintenance is extremely important aspect of solar panel efficiency. Increase in efficiency by 30% to 33% is observed on 8-panel array hence in turn we can observe that it will be of greater use in solar park where number of cells is extremely larger. Complete cleaning is extremely advantageous since the hindering of a single panel with accumulated dust affects the efficiency for the entire array. It is extremely important that all cells operate at peak efficiency since they are connected in series. The existing methods of PV panel cleaning are Natural method and Manual method. Considering these existing methods of solar panel cleaning as above and advantages and limitations of each it is felt that an automatic brush type solar panel cleaning could be ideal as it requires no water or a little water for removal of dust. Also, it is low cost and can be indigenously developed. It also operates and considered as an auxiliary unit of the exiting solar PV system.

8.1 Future Scope

Even though our project worked perfectly and was functioning as initially planned, there are still a lot of improvements that can be made to make it more marketable and efficient. Further development aims at optimizing the system to be smaller, lighter, easier to ensemble in higher volume and more eco-friendly. More focus will be lighted on auto lining features, robustness, speed, and improving the intelligence of the bot overall. Installation of thermal camera module and proximity sensors will allow inspection of the solar panel more easily and improves the contact with every panel. Cleaning more arrays in one go would definitely be a challenge however, design should be more universal so as to fit to almost every panel size all across the globe. Detection of cell damage and panel damage should also be recognized and the whole system should be completely controlled by single remote control. Research public opinion and determine whether people would be willing to pay for the long-term savings that our project promises.

9. REFERENCES

[1] D. **J.B Jawale** and **V.K Karra** (2016), "Solar Panel Cleaning Bot for Enhancement of Efficiency", International conference on Devices, Circuits and Systems, 103-108

[2] M. **Patil P.A** and **Bagi J.S** (2017), "A Review on Cleaning Mechanism of Solar Panel, Photovoltaic Panel", International Conference on Energy, 250-256

[3] **Bandham Abhilash** and **Ashish k Panchal**, "Self-cleaning and tracking solar photovoltaic panel for improving efficiency", 2016.

[4] K. **A Syafiq** and **A K Pandey** "Photovoltaic glass cleaning methods: an overview", 2015

BIOGRAPHIES

Sachin Mathew, B. Tech, Electrical and Electronics Engineering. (2019 Batch) From College of Engineering, Chengannur, Kerala, India.

Maria Susan Abraham, B. Tech, Electrical and Electronics Engineering. (2019 Batch) From College of Engineering, Chengannur, Kerala, India.

Jishnu K S, B. Tech, Electrical and Electronics Engineering. (2019 Batch) From College of Engineering, Chengannur, Kerala, India.

Amina A, B. Tech, Electrical and Electronics Engineering. (2019 Batch) From College of Engineering, Chengannur, Kerala, India.