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Development of Automatic Robotic System for Vacuum Cleaning of Solar Panels

Dr. Venkateshappa[1], Thushal Y[2], AnuShreya[3], Chetan L[4], Anusha B A[5]

[1, 2, 3, 4, 5] *School of Electronics and Communications Engineering, REVA University, India*

ABSTRACT

Solar energy radiated from the Sun is a primary source of energy for Earth. Solar panels use solar radiation and generate energy, and this is used by commercial users and domestic users. Thepower output of solar panel gets reduced due to accumulation of dust particlesand sand on the panels.The solar panels cleaned regularly attract large amounts of sunlight and quantity of electric power generated increases when compared to uncleaned solar panels. Theconventional methods used for cleaning are manual and usewater. To overcome these problems an autonomous cleaning system is designed. It can be used on inclined and slippery surfaces. Robotic navigation and cleaning ofsolar panelsis performed programmatically using electronic systems. Performanceof the system isanalyzed, and results are shown. The system is robust and economical and cleans solar panel arrays which are not inclinedand also those which are inclined.

Keywords: Arduino, Autonomous,Robotic, Solar, Vacuum cleaner.

I. INTRODUCTION

One of the largest energy sources is Sun. There is an enormous quantity of solar energy in nature. There is huge demand for energy in the World. This increases the demand for solar energy which is renewable and inexhaustible. Solar energy is converted to electrical energy using solar panel. There is a rapid increase in use of solar devices since they are economical and offer technical benefits. Therefore, we need to increase the solar panel efficiency.

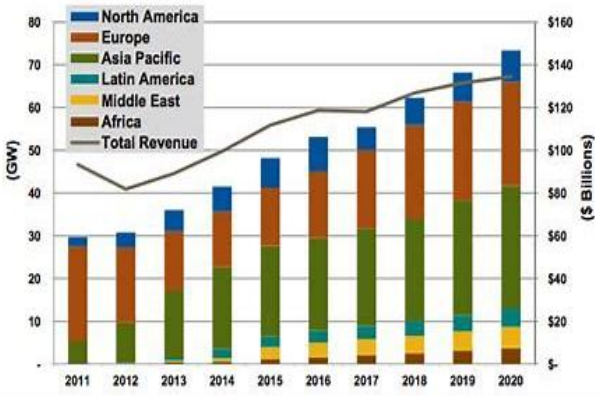


Fig. 1. Annual solar PV capacity and revenue by region.

There is a continuous demand in the market for Solar PV(photovoltaic) cellsworldwide. The conversion rate for solar cells is between 10 % and 13 % for solar cells at the commercial level. This has taken place due to a reduction of 80 % of the cost between the years 2008 and 2015. The price of PV(Photovoltaic) panels hasbeen greatly reduced leading to their increased usage. A primary reasonfor costreduction in solar panel's cost is technological advances in the methods of cleaning. The harnessing of solar energy takes place in areas whose climate is dry and hot. In these areas there is serious problem of dust accumulation. The efficiency is found to decrease by 50%. There is also the problem of overheating. Permanent damage can occur in panels.

Fig. 2. Array of solar panels accumulated by dust.

The cleaningPV panel can be achieved with a high great efficiency, where more than 90% dust particles are removed. Research work is underway to determine alternative solutions where all accumulated dust can be removed. In one of the systems engineered by Aravind and others, the solar panels provide power to the AVCR(autonomous vacuum cleaning robot). A lightweight robot is designed. It traverseson the panels and cleans them. For charging the robot makes use of docking station. Dust particles accumulated on the panels decreases their efficiency.Particulate matter present in atmosphere is dust. It includes fog, smoke,organic and inorganic substances. The collection of these substances results in dust formation. Dust particles can also consist of remnants from forest fires, volcanoes, stormvapors, smoke.Bacteria, sand, and pollen also contribute to dust formation. The action of wind causes movement of dust particles from one place to a different place and can cover large distances. Temperature and clouds which are atmospheric conditions also affect the efficiency of solar panels. The entire solar energy present in atmosphere cannot be used due tothe above factors present in the atmosphere. In the present project there is less power loss. The project can be used easily andis self-reliant. One major advantage of solar energy is it generates electricity without carbon dioxide emission. The mechanism in the projectuses roller for executing motion which is slippage-free and a vacuum motor for cleaning the glassy surface. The cleaning of solar panel is programmatically controlled byatmega328 board. The final goal is development of an electronic cleaning system which automatically cleans solar panels. Solar panels can be manually cleaned but there is risk of accidents and also there is constant requirement of manpower. These are major disadvantages.

The system developed in the present project is efficient and provides smooth cleaning of solar panels by removing

dust deposits. It eliminates irregularities in the generation ofoutput power. The autonomous robot moves on the solar panel's slanted surface and cleans it using a rotating brush. In every cycle there is a movement of robot over a fixed distance in a particular which is parallel to the solar panel's base. Then there is movement of rotating brush in a direction which isperpendicular to the base and the movement isfrom top of the panel to its bottom. In this project we have designed and implemented a robust and economical RVC(Robotic Vacuum Cleaner) which cleans solar panel arrays. The panels can be either inclined or non-inclined.

Problem Statement

The solar panels are used for generating power from the sun radiations reaching the panel. As panels are placed in upwards angle, bird droppings are commonly observed on the panels. They are also exposed todirt, moss,dust and sand which is not carried away by wind or rain. The above factors significantlydecrease the quantity of light falling on the panel. Hence there is reduction in output powerof the solar panel.

II. LITERATURE REVIEW

This research by Thanaphon Sorndach and NoppadolPudcheun designed and developed a robotic system. Thisclimbsup theslippery and inclined solar panels. For this omni-wheels are used by the system. The robotic system moves freely and rotates freely and turning of the robot is avoided while performing the operation [1].

Mohammad. et.al developed a portable robotic cleaning device for moving along the complete length of solar panel.It is practically observed that RCS(robotic cleaning solution) maintains the efficiency of clean PV panels [2].

Hiroyuki et.al Shibata have developed a unique cleaning system by utilizing an electrostatic force to remove sand from solar panels [3].

The system developed by Aravind G, et.aluses two subsystems,Docking Station and RVC(Robotic Vacuum Cleaner). The RVC performs cleaningin two-stages for removal of dust particles from solar panels [4].

Milin D Patil, et.al, presented a cleaner which consists of brushes, DC motors and stepper motor and this performs accurateoperation in both horizontal and vertical directions [5].

III. METHODLOGY

Hardware design

1. ATMEGA 328P

Fig. 3. Arduino

The Arduino Uno is an open-source microcontroller which consists of 14 digital pins and 6 analog pins. Arduino Uno is programmedusing IDE(Integrated Development Environment). An USB cable can be used for powering the Arduino Uno. Other power sources include 9-voltexternal battery, and voltage sources which provide voltage in the range 7 to 20 volts.

2. IR SENSOR

Fig. 4. IR Sensor

One type of electronic device which quantifies infrared radiation present in the surrounding environment is the LM358 IR (infrared) sensor.Any device emitting heat generates IR(infrared) radiation. The two systems present in IR sensors are receiver and LED(light emitting diode). If an object is in proximity, the sensor's, LED transmits infrared light. This light is reflectedby the object. The receiver detects the light and provides output.

3. DCMOTOR

Fig. 5. DC Motor

Conversion of electrical energy to mechanical energy is performed using DC motor. It is a lightweight motor usually used in toys and trolleys etc. The speed of the DC motor can be controlled by gears. The different varieties in DC motors areelectronic type or electromechanical type. In all the motors there is a periodic change in the current direction.

Software design

START

Define inputs (IR1, IR2, IR3)

Define inputs (IN1, IN2, IN3)

Define function panelnavigate

If (IR1 & IR2 & IR3 ==1)

Forward()

If ((IR1 & IR3 ==0) & IR2 ==1)

Stop()

If (IR1 ==1 & (IR2 & IR3==0))

Left()

If (IR3 ==1 & (IR1 & IR2==0))

Right()

Define function Forward, Stop, Left, Right

STOP

IV. IMPLEMENTATION

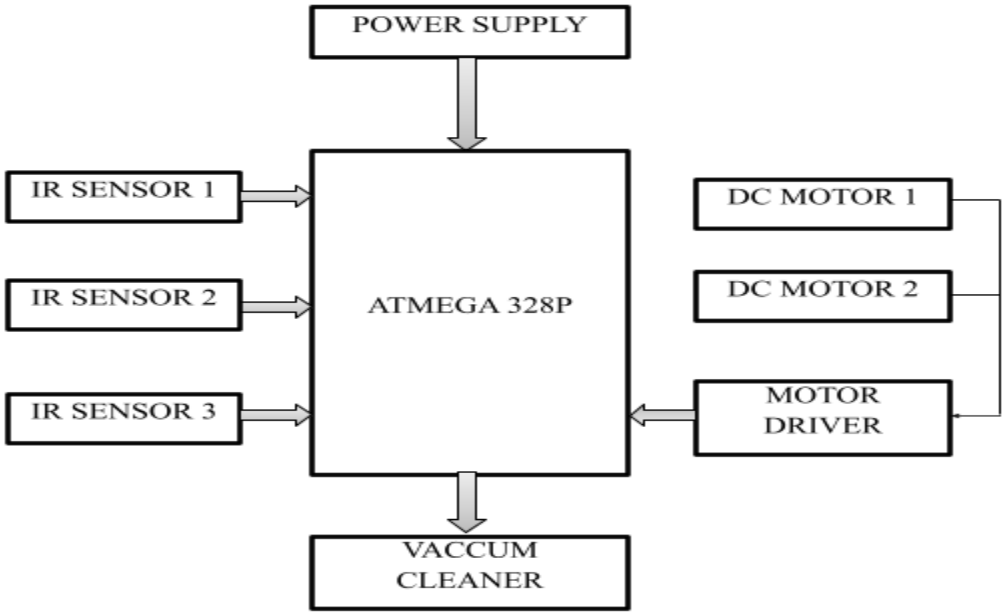


Fig. 6. Cleaning System's block diagram

The block diagram of the cleaning system is shownin Figure 3. Power supply is the main source for any of the electronic components. The power supply what we get from the main supply is 230V AC supply. This power supply should be reduced to the required voltage, the required voltage of the components used is 5V DC. To reduce this voltage there are many components used i.e., transformer, rectifier, filter, voltage regulator through which the supply is reduced to 5VDC. The supply used is divided to all components i.e., microcontroller, IR sensor, DC motor, vacuum cleaner, and the brushes.

The microcontroller used here is ATMEGA328p i.e., Arduino UNO the required voltage for this controller is 7 to 12V dc. This microcontroller controls the complete unit, the cleaning part, the vacuum part, and robot's movementon solar panel. This was the best suitable controller for this project hence it is used.

IR sensors is the input device used here which is connected to the microcontroller itself. The LM358 IR sensor detects if there is any dust particle on the solar panel and cleans it. It is also used for checking the path for the panel.

The DC motors used are geared DC motors which give high efficiency and works under 5v. This DC motor is used here to control the robot movement i.e., moving the robot forward, backward, right and left. To control these movements DC motors cannot be used directly.

A L293D DC motor driver is used for movement of the motor in clockwise and anticlockwise direction. There are two methods of cleaning: two circular brushes and the vacuum cleaner. Vacuum cleaner pump GFM0412SS is used to remove the particles of dust present onthe panel. Brushes wipe off the remaining dust. We have also incorporated a WIFI module. This WIFI module allows us to control the robot manually.

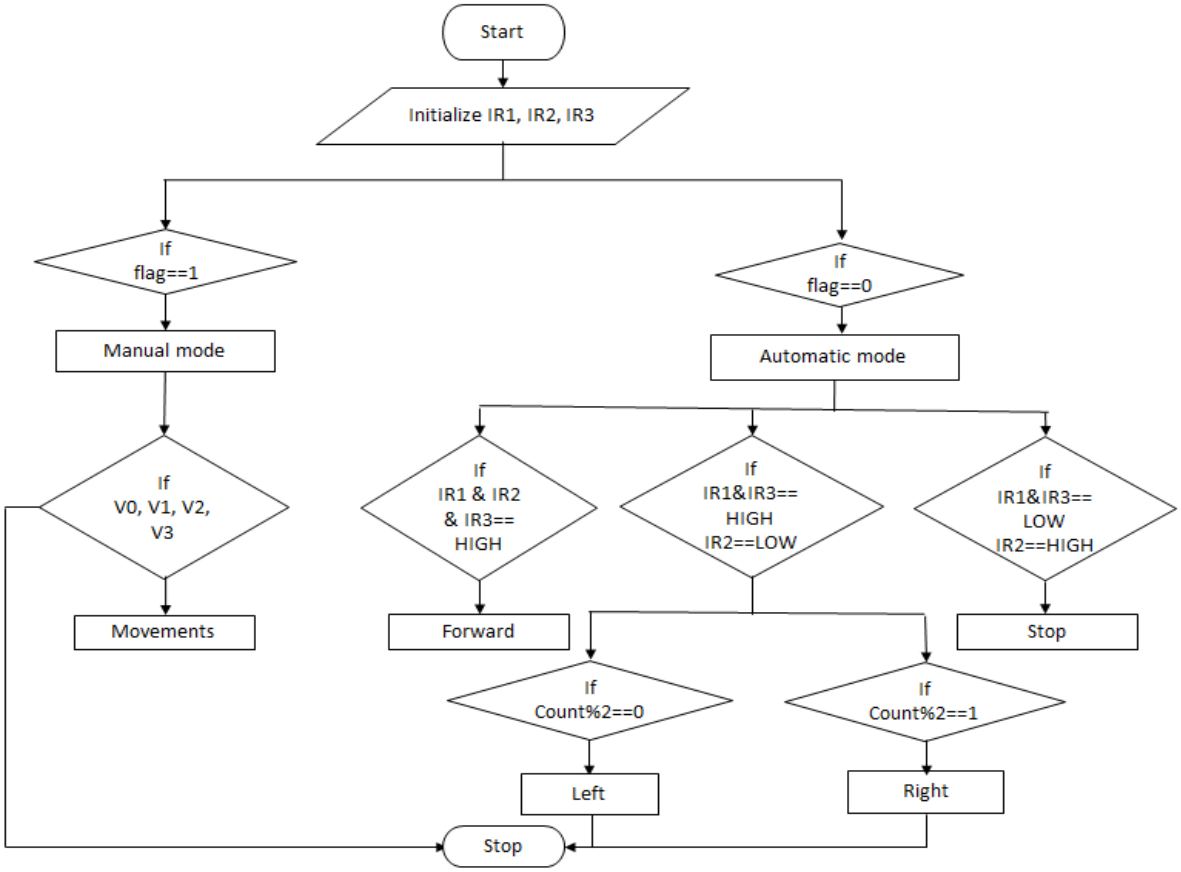


Fig. 7. Flow Chart of the Path.

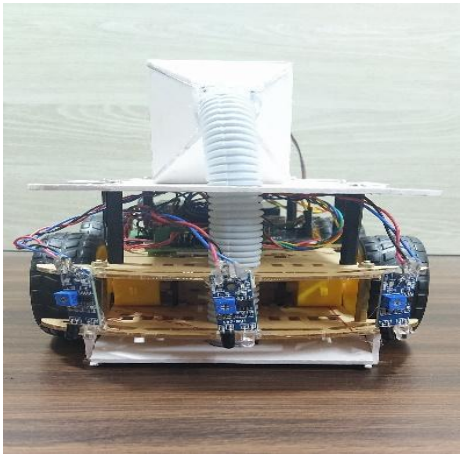
- The machine is initialized at the beginning as it is powered ON.
- All the sensors (IR1, IR2,IR3) are initialized to LOW.
- The switch condition is checked, If the switch is turned ON then the machine works in Manual mode (remotely

accessible) else it is set to Automatic Mode.

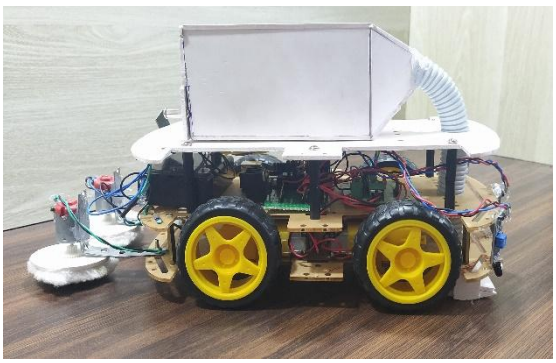
- When the machine is set to Manual Mode all the controls are from the remotely controlled device as per the needs of the user
- When the machine is in Automatic Mode. All the sensors are triggered.
- When IR1, IR2 and IR3 are HIGH the machine moves in forward direction.
- When IR1 is HIGH the machine turned to its left by 90^0 and moves forward for 1sec and then turns left by $90^0$and moves forward until the next sensor is triggered.
- When IR3 is Triggered HIGH, the machine turned to its right by 90^0 and moves forward for 1sec and then turns right by 90^0 and moves forward until the next sensor is triggered.
- When IR1 and IR3 are triggered LOW and IR2 is HIGH then the machine is set to a halt and stops. The machine then requires a manual start to work again.

V. RESULT

The proposed robotic cleaner is designed to clean with the help of vacuum motor- GFM0412SS and two circular brushes as show in Fig. 5. Firstly, the vacuum in the front-end sucks in the dust from the panels and then the brushes wipe off the remaining dust. From Fig. 6. We can see the robot cleaning the panel. After several case studies, we can predict that our system can yield up to 60-70% overall efficiency.



(a)



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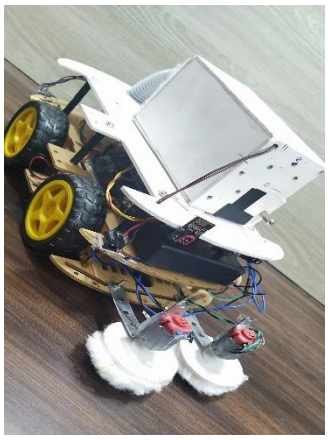

(c)

Fig. 8. Figure of the robotic cleaner from the front(a) from the lateral (b) (c)

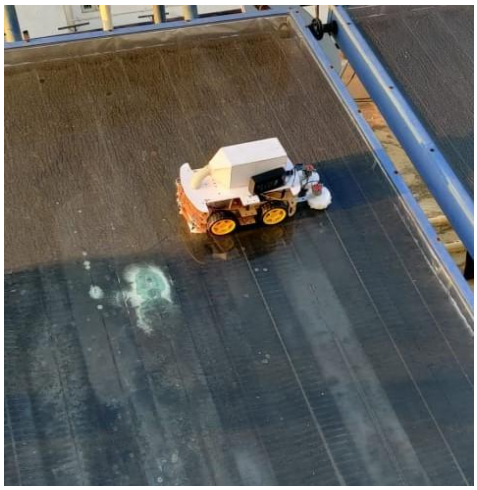

Fig. 9. Cleaning process

VI. CONCLUSION

For using the entire solar energy which falls on the solar panels, it must be ensured that cleaning of solar panel takes place. It is not convenient to clean the panel on a daily basis and also is difficult. Therefore, there is a need for automatic cleaning of solar panels.Thisensures an increase in energyproduction. The brush used for cleaning is oriented vertically. The vacuum pump cleans the small dust particles on the solar panel. Our system becomes beneficial for cleaning solar panels on small and large scales.

5.1 APPLICATIONS

- In solar parks for leaning large solar panels.
- For cleaning panels on the roof tops of houses and commercial property.
- To clean high rise windows and buildings.

5.2 ADVANTAGES

- It is a compact and efficient robot which takes tangible inputs from the environment for the cleaning process.
- It performs task for long intervals i.e., it has a good battery backup.
- The movement in workspace takes place automatically and human intervention is not needed.
- A battery and DC supply power the robot.

5.3 FUTURE SCOPE/LIMITATIONS

- To reduce the occurrence of slipping it is proposed to developOW(omni wheel)robot making use of material which possess high friction.
- When a sticky material gets stuckon the panel, a harder brush needs to be used for the removal.
- The robot's weight must be reduced for increasing the lifetime of battery and this results in longer use.

VII. ACKNOWLEDGEMENTS

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