

IMPROVISATION OF SOLAR CELL EFFICIENCY

Submitted in partial fulfillment of the requirements for the award of Masters of Engineering degree in Electronics and Communications Engineering.

by

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**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **MOHAMMED MAAZ.A (38130139)** and **RAGHUL.G (38130177)** who carried out the project entitled **IMPROVISATION OF SOLAR CELL EFFICIENCY** under my / our supervision from December 2021 to May 2022.

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We **MOHAMMED MAAZ.A (38130139)** and **RAGHUL.G (38130177)** hereby declare that the Project Report entitled **IMPROVISATION OF SOLAR CELL EFFICIENCY** done by us under the guidance of Dr. G D Anbarasi Jebaselvi, M.E., Ph.D., is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communications Engineering.

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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 photovoltaic (PV) panels. The large-scale adoption of renewable energy throughout the world is increasing. Solar energy is the abundant renewable energy on earth which doesn't pollute the environment while producing the energy using Solar Photo Voltaic (PV) panel. Efficiency of the PV panel depends on the amount of light falls on it, due to the azimuth angle of solar panel, deposition of dust on PV panel reduces the efficiency of the energy generated. To increase the efficiency of the PV panel, periodically it has to be cleaned. This proposed model is a solar panel cleaning system which periodically cleans PV panel autonomously, the surface of the panel is cleaned by spraying the liquid and wiping out the dust with wiper. The proposed system is controlled remotely by Embedded systems which reduces the human effort in the solar plant and can be remotely monitored. Also, the system self-power generates the power required by Solar PV panel mounted on the system. The proposed system increases the efficiency of the power generation by periodically cleaning.

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CHAPTER 1

INTRODUCTION

There is more than enough solar radiation available around the world to satisfy the demand for solar power systems. The proportion of the sun's rays that reaches the earth's surface is enough to provide for global energy consumption 10,000 times over. On average, each square metre of land is exposed to enough sunlight to produce 1,700 kWh of power every year.

The statistical information base for the solar energy resource is very solid. The US National Solar Radiation database, for example, has logged 30 years of solar radiation and supplementary meteorological data from 237 sites in the USA.

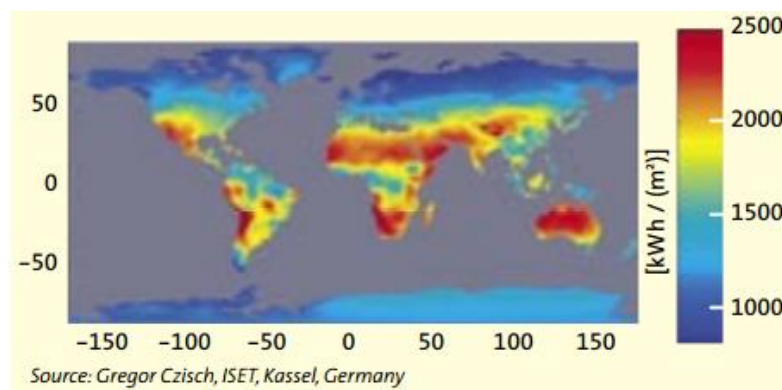


Fig.1.1 Global variations in irradiation

Figure 1.2 shows the estimated potential energy output from solar PV generators in different parts of the world. The calculation used here takes into account the average efficiency of modules and converters as well as the correct angle to the sun required at different latitudes.

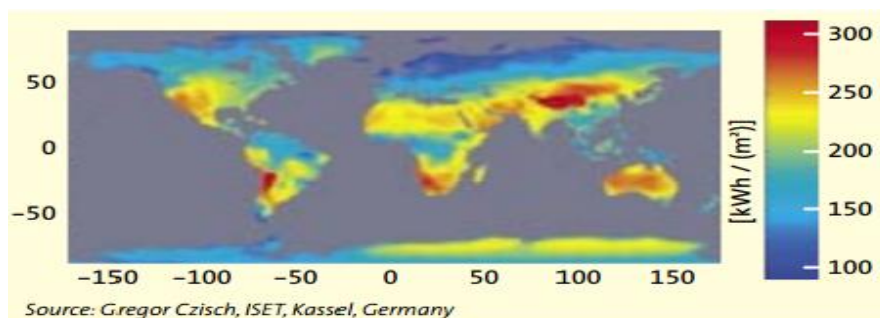


Fig.1.2 Energy potential from PV around the world

1.1 PHOTOVOLTAIC ENERGY

“Photovoltaic” is a marriage of two words: “photo”, meaning light, and “voltaic”, meaning electricity. Photovoltaic technology, the scientific term used to describe what we use to convert solar energy into electricity, generates electricity from light. We use a semi-conductor material which can be adapted to release electrons, the negatively charged particles that form the basis of electricity. The most common semi-conductor material used in photovoltaic (PV) cells is silicon, an element most commonly found in sand.

All PV cells have at least two layers of such semi-conductors, one positively charged and one negatively charged. When light shines on the semi-conductor, the electric field across the junction between these two layers causes electricity to flow, generating DC current. The greater the intensity of the light, the greater the flow of electricity.

A photovoltaic system therefore does not need bright sunlight in order to operate. It also generates electricity on cloudy days by a rationing of the energy output that depends on the density of the clouds. Due to the reflection of sunlight, days with slight cloud can even result in higher energy yields than days with a completely cloudless sky. Generating energy through solar PV is quite different from how a solar thermal system works, where the sun’s rays are used to generate heat, usually for hot water in a house, swimming pool etc.

1.2 SOLAR PANEL

Solar panel refers to a panel designed to absorb the sun's rays as a source of energy for generating electricity or heating.

A photovoltaic (PV) module is a packaged, connect assembly of typically 6×10 solar cells. Solar Photovoltaic panels constitute the solar array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions, and typically ranges from 100 to 365 watts. The efficiency of a module determines the area of a module given the same rated output – an 8% efficient 230-watt module will have twice the area of a 16% efficient 230-watt module. There are a few commercially available solar panels available that exceed 22% efficiency and reportedly also exceeding 24%. A single solar module can produce only a limited amount of power;

most installations contain multiple modules. A photovoltaic system typically includes a panel or an array of solar modules, a solar inverter, and sometimes a battery and/or solar tracker and interconnection wiring.

The price of solar power has continued to fall so that in many countries it is cheaper than ordinary fossil fuel electricity from the grid (there is "grid parity").

1.3 SOLAR PLANTS

Solar energy is the energy from sun radiation. This energy can be harnessed as solar thermal energy and solar photovoltaic. Solar power plant uses solar PV to generate energy, let us see in detail how solar power plant works.

Solar panel generate DC power when sun rise directly hit the panel. This DC power intern feed into an inverter that convert it to an AC power. This AC power is feed in to your distributor board from their it flows to the electrical load. This is the basic layout of solar plant.

But solar plant needs some backup source. The backup power source could be grid for instant or a storage mechanism as battery. Why is this backup required, the sunshine is not constant it varies during the day due to the whether change? A passing cloud can reduce the amount of sunshine hitting the solar panel reducing the power generation. This variation in some condition can damage the load. In order to avoid this problem, the power from solar plant is linked with the power from other source. By using this solar power with other source, we can ensure that load receive steady safe and reliable power,

Solar power plant can be integrated with

1. GRID TYPE

In this grid type plant, they have no other backup power source. This is known as grid type plant as it is always in sink with grid. This is recommended to plant only to organisation that has a guaranteed supply of grid power. This will not suit you if you suffer from frequent power interruption.

2. OFF GRID TYPE

This type does not integrate with grids instead it only integrates with battery bank and diesel generation. This can be used in location that are not connected the grid at all. This can be used for home application.

3.HYBRID TYPE

In this type the solar power plant can be integrated with grid as well as battery and diesel generation. This is recommended to plant who has grid power but with frequently interruption and need with critical load to be powered continuously. Most of the industrial and commercial consumer in India are under this category and required this type of solar plant

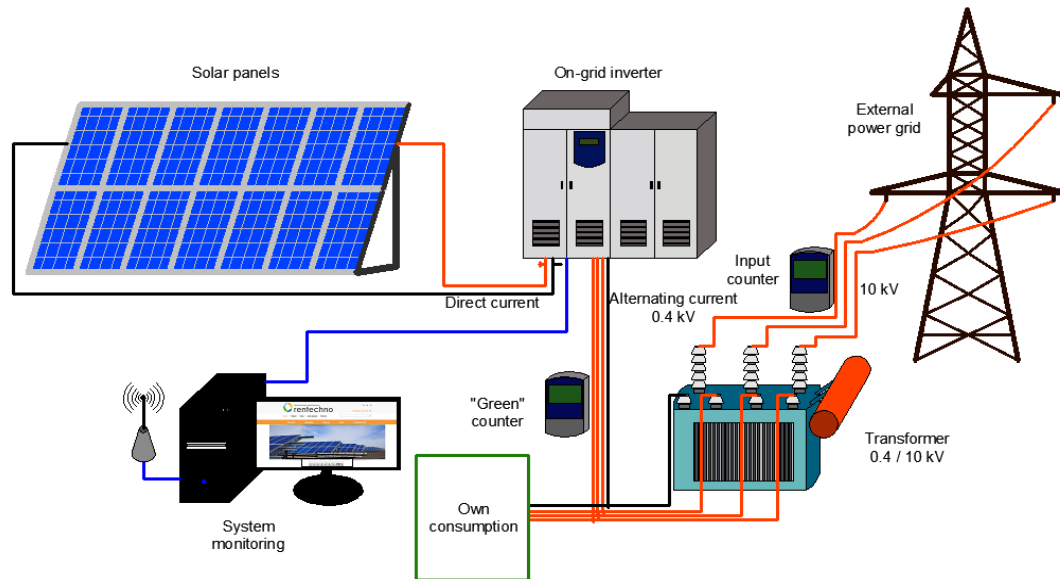


Fig.1.3 Solar Power Plant

CHAPTER 2

LITERATURE SURVEY

The recent upsurge in the demand of PV systems is due to the fact that they produce electric power without hampering the environment by directly converting the solar radiation into electric power. Solar energy is completely natural, it is considered a clean energy source. So the study on improving the efficiency of solar panel is very necessary. Various methods of efficiency improvement of solar panel, we can improve efficiency of solar panel by using solar tracker with panel which continuously tracks sunlight throughout the day to get maximum solar energy. Second method to improve the efficiency is dust cleaning. Dust is barrier between sunlight and solar panel. Third method is cooling technique. As panel temperature increases output voltage of solar panel decreases so cooling of panel is necessary for improvement of efficiency.

Shading and overheating of photovoltaic cells can result in a significant energy reduction of PV systems. Tilting and natural ventilation allows the build up of fine sand to be blown off from the PV array's surface. However, dust particles tend to gradually accumulate on the PV surface making the cleaning task more difficult and reduces the overall PV panel efficiency due to the combined effect of shading and heating.

Accumulation of dust from the outdoor environment on the panels of solar photovoltaic (PV) system is natural. There were studies that showed that the accumulated dust can reduce the performance of solar panels, but the results were not clearly quantified. The objective of this research was to study the effects of dust accumulation on the performance of solar PV panels. Experiments were conducted using dust particles on solar panels with a constant-power light source, to determine the resulting electrical power generated and efficiency. It was found from the study that the accumulated dust on the surface of photovoltaic solar panel can reduce the system's efficiency by up to 50%.

Current labour-based cleaning methods for photovoltaic arrays are costly in time, water and energy usage and lack automation capabilities. In this paper a novel design is presented for the first ever human portable robotic cleaning system for

photovoltaic panels, which can clean and maneuver on the glass surface of a PV array at varying angles from horizontal to vertical.

In order to regularly clean the dust, an automatic cleaning system has been designed, which senses the dust on the solar panel and also cleans the module automatically. This automated system is implemented using 8051 microcontroller which controls the DC gear motor. This mechanism consists of a sensor (LDR). While for cleaning the PV modules, a mechanism consists of a sliding brush has been developed. In terms of daily energy generation, the presented automatic-cleaning scheme provides about 30% more energy output when compared to the dust accumulated PV module (module kept stationary on ground).

A small but important uptick in electrical output from the solar panels on NASA's Mars Exploration Rover Spirit this month indicates a beneficial Martian wind has blown away some of the dust that has accumulated on the panels.

The cleaning boosts Spirit's daily energy supply by about 30 watt-hours, to about 240 watt-hours from 210 watt-hours. The rover uses about 180 watt-hours per day for basic survival and communications, so this increase roughly doubles the amount of discretionary power for activities such as driving and using instruments. Thirty watt-hours is the amount of energy used to light a 30-watt bulb for one hour. The last prior cleaning event that was as beneficial as this one was in June 2007. Winds cleaned off more of the dust that time, but a dust storm in subsequent weeks undid much of the benefit.

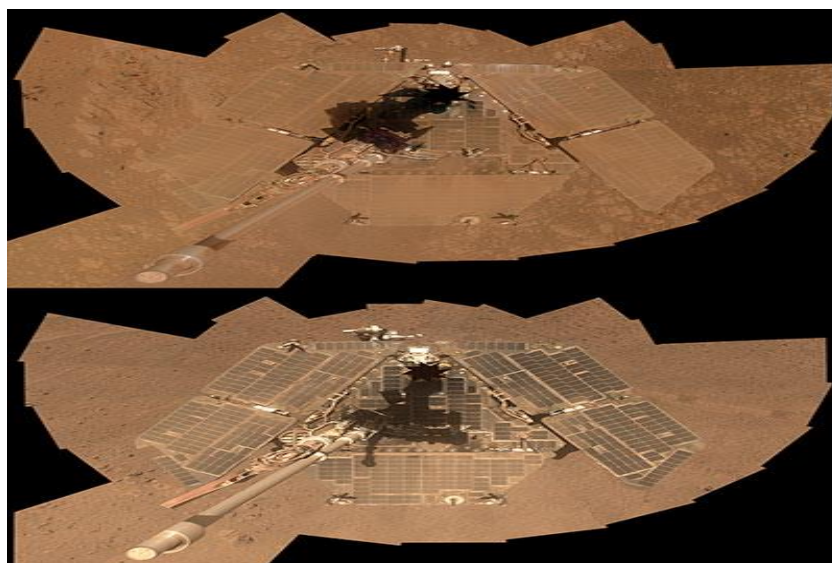


Fig.2.1 NASA's Mars Exploration Rover

CHAPTER 3

HISTORY OF PHOTOVOLTAIC ENERGY

Every day, the surface of planet earth is blasted with so much solar energy that, if harnessed, 60 seconds worth could power the worlds total energy requirements for one year. The sun is a colossal fusion reactor that has been burning, for more than 4 billion years. In just 1 day, it provides more energy than the current human population would consume in 27 years. By some estimates, the amount of solar reaction striking the earth every 72 hours is equivalent to all energy stored in the planet's coal, oil and natural gas reservoirs. Solar radiation is free and natural recourse, yet converting into an energy source is a relatively new idea.

The devices used in photovoltaic conversion are called solar cells. When solar radiations fall on this device, it is converted directly into DC electricity. The principal advantages associated with solar cells are that they have no moving parts, required little maintenance and work quite satisfactorily with beam or diffused radiation. Also, they are readily adapted

The use of photovoltaic energy (aka. solar cells) started way back in 1876. William Grylls Adams along with a student of his, Richard Day, discovered that when selenium was exposed to light, it produced electricity. An electricity expert, Werner von Siemens, stated that the discovery was "scientifically of the most far-reaching importance". The selenium cells were not efficient, but it was proved that light, without heat or moving parts, could be converted into electricity.

In the year 1956, the first solar cells are available commercially. The cost however is far from the reach of everyday people. At \$300 for a 1-watt solar cell, the expense was far beyond anyone's means. 1956 started showing us the first solar cells used in toys and radios. These novelty items were the first item to have solar cells available to consumers.

In the early 1970's a way to lower to cost of solar cells was discovered. This brought the price down from \$100 per watt to around \$20 per watt. This research was spearheaded by Exxon. Most off-shore oil rigs used the solar cells to power the waning lights on the top of the rigs. The period from the 1970's to the 1990's saw quite a change in the usage of solar cells.

Today we see solar cells in a wide variety of places. You may see solar powered cars. There is even a solar powered aircraft that has flown higher than any other aircraft with the exception of the Blackbird. With the cost of solar cells well within everyone's budget, solar power has never looked so tempting.

Recently new technology has given us screen printed solar cells, and a solar fabric that can be used to side a house, even solar shingles that install on our roofs. International markets have opened up and solar panel manufacturers are now playing a key role in the solar power industry.

A cleaning event is a phenomenon whereby dust is removed from solar panels, particularly ones on Mars, by the action of wind. The term cleaning event is used on several NASA WebPages; generally, the term is used in reference to the fact that Martian winds have blown dust clear off the solar panels of probes on Mars increasing their energy output

The term started being used in 2004 as the Mars Exploration Rovers' solar panels started to benefit from these events. The rovers were expected to last about 90 sols (Martian days) on Mars, after which dust would cover their solar panels and reduce solar power to levels too low for the rovers to operate. However, power levels went back up due to the cleaning events caused by the winds in the Martian atmosphere. Periodic cleaning events have allowed the MER rovers to operate far longer than the planned 3 months. While Spirit rover finally ceased operation in 2011, Opportunity rover remains active as of 2017, more than 13 years after landing.

Cleaning events can either be rapid, such as overnight, or over many days where solar power slowly goes up. For example, the MER-A Spirit rover, on April 18, 2009 and April 28, 2009 the power output of the solar arrays were increased by cleaning events. The power output of Spirit's solar arrays increased from 223-watt hours per day on March 31, 2009 to 372-watt hours per day on April 29, 2009. Other factors that affect solar power output include the opacity of the Martian atmosphere and Martian seasonal changes. The Materials Adherence Experiment had a glass plate that allowed the dust to be cleared off and protected a Gallium arsenide photo-cell. It was part of the Mars Pathfinder program in the 1990s.

CHAPTER 4

PROBLEM DEFINITION

4.1 PROBLEMS FACED IN SOLAR POWER PLANT

Solar energy is a sustainable energy source. It is renewable as well. It has many applications like solar water heaters, solar air heaters and electricity generation. It has its advantages as well as disadvantages. Some of the disadvantages are

1. Low efficiency of solar power conversion.
 2. Initial cost incurred in purchasing solar panels and their installation is fairly high enough to think about it twice.
 3. Obviously, the plant won't be in working condition during night time.
- The weather is also a big factor in reducing the efficiency of solar system used.

4.2 LOW EFFICIENCY IN SOLAR POWER PLANTS

Besides solar panels efficiency and size, there are other factors that affect how much power your solar panels will create. Living in Arizona will get more solar radiation than someone who lives in the mid west. Solar energy output is also affected by weather and seasonal variations. The angle of the sun to the solar panel changes with the time of day and seasonal variations. Cloudy and rainy days also contribute to less effectiveness of the sunlight collection.

4.2.1 Solar panel pitch and orientation

A non-tracking PV system in the Northern Hemisphere should face true south. The positioning angle directly relates to the angle of latitude, if you live at 35.2 degrees North of the equator (Flagstaff, AZ), your panel should face directly South at a 35.2-degree angle. Remember that if the solar panels are being installed on a roof, take into account the pitch of the roof.

For maximum performance adjust your solar panels twice a year. In the summer months the sun is high overhead, catch more sunlight by tilting solar panel at a lower angle. During the winter, the sun moves across the sky at a lower angle, angle solar panels higher during these months. Large commercial systems have solar tracking systems that automatically follow the sun's tilt through the day. Due to their high costs, they are not typically used for residential solar installs.

4.2.2 Temperature

High temperature can severely reduce the solar panel's production of power. Higher temperature increases the conductivity of the semiconductor, charges become balanced within the material, reducing the magnitude of the electric field, inhibiting the charge separation, which lowers the voltage across the cell. Depending on the location, heat can reduce the output by 10% to 25%.

In the built environment, there are a couple of ways to deal with high temperature. Install solar panels on a mounting system a few inches off the roof, this will help cool them by allowing air circulation. Use photovoltaic panels that are designed to be more efficient in hotter climates. Ensure that panels are constructed with light-colored materials, to reduce heat absorption. Inverters and combiners can be moved into the shaded area behind the array.

4.2.3 Shade

Shade can be the enemy of solar power. The way solar is designed even a little shade on one panel can shut down solar production on all the other panels. Solar cells are connected in series, and will operate at the current level of the weakest cell, if one solar cell is shaded it will adversely influence the output of all other cells. When deciding on a location for your solar panels do a shading analysis, make sure no shadows will fall on the solar panel array during peak sunlight hours. This may mean trimming a few trees.

4.2.4 Dust and Dirt

Solar cells can not absorb light as effectively when the surface of the solar panels is covered with dirt or birds' droppings, which doesn't get washed by the rain. Making frequent physical inspections and spraying water on your modules can help reduce the problem.

This can reduce output and efficiency of the system completely if left untreated for years. A typical cleaning will result in a 10%-60% increase in efficiency.

4.3 REMOVAL OF DUST AND DIRT

Dusty environment accumulation of dust on the solar panels leads to reduction of the transmittance of the panel. Solar desalination plants in some of the middle-east countries like the solar desalination plant of Abu Dhabi suffers from the deposition of

dust on its solar plates. The effect of the accumulated dust will be reduced with the increasing of tilt angle, since the tilt angle will affect the exposure time to the sunlight also. But the best way to eliminate the effect of the accumulated dust on the solar panels is to clean the panels. Cleaning the solar panels is normally by washing which is tedious and cumbersome and also expensive in terms of the labour involved and time. In practice cleaning of solar panels should be frequently done.

The cleaning method is summarized as natural means, mechanical means.

4.3.1 Natural removal of dusts

The natural powers are employed to remove the dusts, such as wind power, gravitation and the scour of the rainwater. The effect of this method is not very well. Gaier J, Davis P and Marabito reported that they had studied the validity of this method. It is viable that the solar cell array can be turned to vertical or oblique position to remove the dusts easily when early morning, late evening, night and a rainy day. However, the rotation of the large solar cell array is very difficult.

4.3.2 Manual removal of dusts

The mechanical methods remove the dusts by brushing, blowing, vibrating and ultrasonic driving. The brushing methods clean the solar cell with something like the broom or brush that were driven by the machine was designed just like windscreen-wiper. However, firstly, because of the small size and the strong adhesively of the dusts, the cleaning method is inefficient. Secondly, the abominable working environment of the solar cell makes the maintenance of the machine difficult. Then, due to the large area of the solar cell array, the cleaning machine is powerful. Lastly, the surfaces of the solar cell maybe were damaged by the brush when wiping. The blowing method cleaning the solar cell with wind power is an effective cleaning one except the low efficiency, high energy-consumption and the unsatisfactory maintainability of the blower.

MONTHLY CLANING STATEMENT AS PER THE VIKRAM SOLAR POWER PLANT

During our visit to vikram power plant the data collected from there was very significant to prove that the manual/labor-based cleaning system is costlier and time consuming, the data collected is as follows

- The cleaning process is outsourced and the costing done for this process is 45paise/panel.
- Vikram solar power plant is a 17MW pant spread over a area of 100acres.
- 1MW consists of 4,252 panels and the total plant consists of 72,284 panels.
- Therefore, the cost involved to clean the plant for once is 32,527RS.
- Cleaning is done 4 times a month.
- Total annual cost for cleaning is = 15,61,296RS.

Since manual cleaning costs more and require more time for cleaning the panels.

In practice cleaning of solar panels should be frequently done which makes the process more laborious and expensive. Hence an innovative method of automatic cleaning of solar panel has been proposed.

CHAPTER 5

OBJECTIVE

5.1 PROJECT GOALS

- Design a mechanism to detect obstructions on solar panels causing significant loss of power.
- Design a cleaning mechanism that runs across the length of the panels.
- Improve overall solar panel efficiency.
- The main and the foremost objective of this project is to design and implement microcontroller based solar panel dust cleaning system.
- The proposed system aims to provide an effective, non-Abraisive cleaning.
- Non-Abraisive cleaning is all purpose cleaning which is to clean all types of solar panel.
- Avoid the irregularities in the output due to the deposition of dust.
- Also, it aims to work in even the most extreme conditions like in deserts.

5.2 FEATURES

- To increase the efficiency of the plate.
- To increase life of the plate.
- To reduce cleaning cost of the cleaning process.
- To reduce the labour cost.
- To reduce the time of the cleaning.
- Automatic cleaning system.
- Controlling by it self.
- To remove dust particles.

CHAPTER 6

METHODOLOGY

The cleaning unit moves on the central part of the panel in a back-and-forth motion. The wiper mounted on the fixture and tool unit reciprocates in the forward and backward direction. The cleaning unit along with the wiper moves along the central panel spraying the water droplets towards the other end of the panel. It forces the dust to move in the direction of the motion of the cleaning unit and finally flows it away at the edge of the panel. Once the cleaning unit reaches the other end, the water spraying stops and it again returns back. Once it reaches the home position, The cleaning unit stops here i.e., tool.

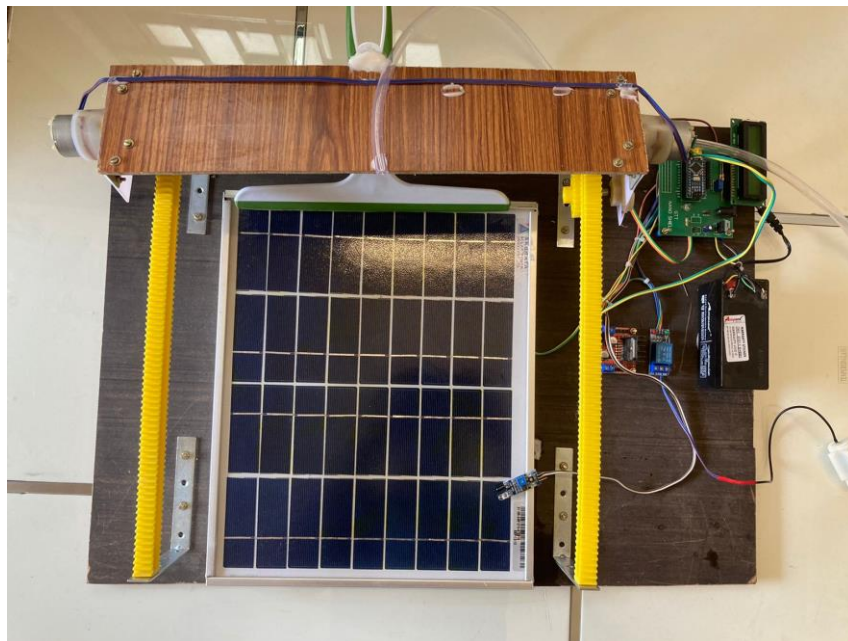


Fig6.1 Solar Panel Cleaning System

6.1 MECHANICAL COMPONENTS

6.1.1 Rack and pinion:

Rack and pinion are used to convert a rotary motion into translating motion or vice versa (either the pinion drives the rack or the rack drives the pinion). Fig. Shows a rack in mesh with a pinion. The rack and pinion are used in consolidating the lap in scutcher of conventional blow rooms (rack drives the pinion) and to drive the bobbin carriage of moving machines (pinion drives the rack). Rack can be imagined as a spur

gear having an infinitely larger diameter. Therefore, the rack has an infinite number of teeth and a base circle which is infinite distance from the pitch point. With infinite diameter of base circle, the involute outline of teeth on rack became straight lines.

Specifications of Rack and pinion:

- **Material** - Plastic
- **Colour** - yellow
- **No. of teeth on Pinion** - 16
- **Diameter of Pinion** -
- **Length** - 146mm
- **Height** - 8mm
- **Width** - 8mm



Fig6.2 Rack and Pinion

6.1.2. DC gear motor:

L293d motor driver

The L293 and L293D are quadruple high-current half-H drivers. The L293 is designed to provide bidirectional drive currents of up to 1 A at voltages from 4.5 V to 36 V. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. Both devices are designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications.

Darlington source. Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled, and their outputs are active and in phase with their inputs. When the enable input is low, those drivers are disabled, and their outputs are off and in the high-impedance state. With the proper data inputs, each pair of drivers forms a full-H (or bridge) reversible drive suitable for solenoid or motor applications.

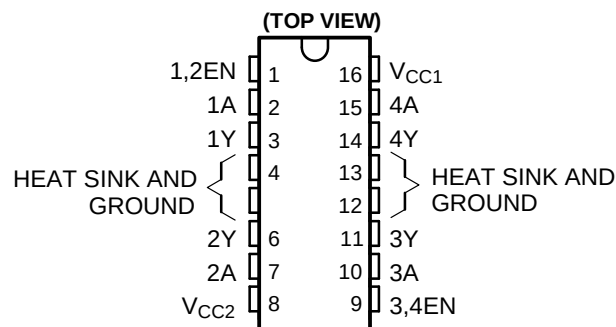


Fig 6.3 PIN Diagram L293D Motor Driver

On the L293, external high-speed output clamp diodes should be used for inductive transient suppression. A V_{CC1} terminal, separate from V_{CC2} , is provided for the logic inputs to minimize device power dissipation.

The L293 and L293D are characterized for operation from 0°C to 70°C.

BLOCK DIAGRAM

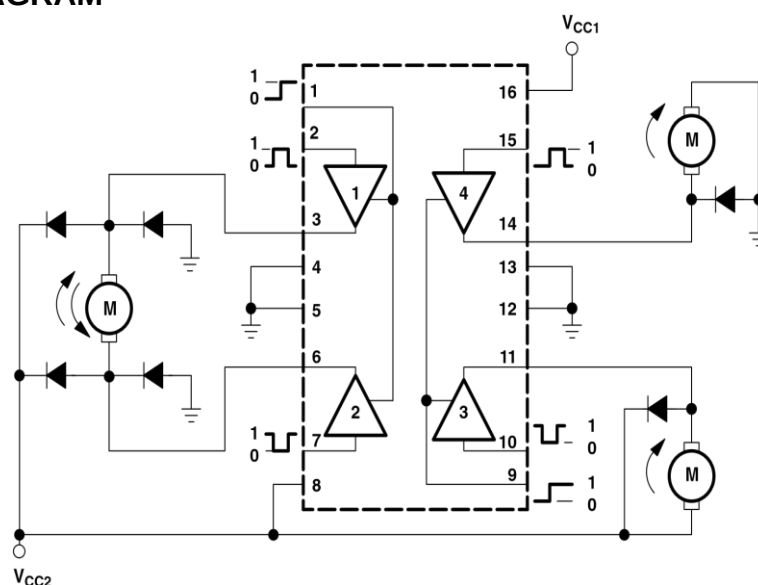


Fig 6.4 Block diagram of L293D Motor Driver

NOTE: Output diodes are internal in L293D.

FUNCTION TABLE (Each driver)

INPUTS		OUTPUT Y
A	EN	
H	H	H
L	H	L
X	L	Z

Fig 6.5 Function Table of L293D Motor Driver

H = high level, L = low level, X = irrelevant,

Z = high impedance (off)

in the thermal shutdown mode, the output is in the high-impedance state, regardless of the input levels.

LOGIC DIAGRAM

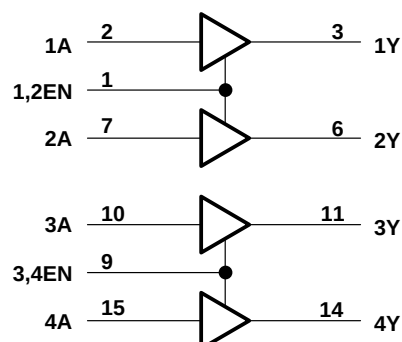


Fig 6.6 Logic Diagram of L293D Motor Driver

Specification of DC motor:

- Voltage: 2.5-6V
- Maximum lift: 40-110cm / 15.75"-43.4"
- Flow rate: 80-120L/H
- Outside diameter: 7.5mm / 0.3"
- Inside diameter: 5mm / 0.2"
- Diameter: Approx. 24mm / 0.95"
- Length: Approx. 45mm / 1.8"
- Height: Approx. 30mm / 1.2"
- Material: Engineering plastic
- Driving mode: DC design, magnetic driving

APPLICATIONS

- Controlled fountain water flow
- Controlled Garden watering systems
- Hydroponic Systems
- Fresh water intake or exhaust systems for fish aquarium



Fig.6.7 DC gear motor

6.1.3. Water pump dc 12v

This is a small size submersible pump motor which can be operated by 2.5V~6V power supply. It can pump up to 120 litre per hour with very low current consumption of 220mA.



Fig.6.8 Water Pump

Specifications:

- **Operating Voltage** - 2.5to 6V
- **Operating Current** - 130 to 220mA
- **Flow Rate** - 80 to 120 L/H
- **Maximum lift** - 40 ~ 110mm
- **Material** - Engineering Plastic

6.1.4. Wiper

A wiper generally consists of a metal arm, pivoting at one end and with a long rubber blade attached to the other. The arm is powered by a motor, often an electric motor, although pneumatic power is also used in some vehicles and cleaning the glass surfaces. The blade is swung back and forth over the glass, pushing water or other precipitation from its surface. The speed is normally adjustable, with several continuous speeds and often one or more "intermittent" settings.



Fig.6.9 Wiper

6.2 ELECTRICAL COMPONENTS

6.2.1. Solar panel

Solar panel absorbs the sunlight as a source of energy to generate **electricity** or **heat**. Interconnected silicon cells joined together to form a circuit. At cell structure level, different kinds of panels exist, such as monosilicon, polysilicon or thin-film.

- **Solar Cell:** Semiconductor device that converts sunlight into director current (DC) electricity.
- **Module:** PV module consists of PV cell circuits sealed in an environmentally protective laminated and are the fundamental building block of PV system.
- **Solar Panel:** Includes one or more PV modules assembled as a pre-wired, field-instable unit.
- **String:** A string is a group of modules wired in series. Basic electrical physics tells us that connecting electrical sources in series increases voltage, which is exactly the goal of a string.

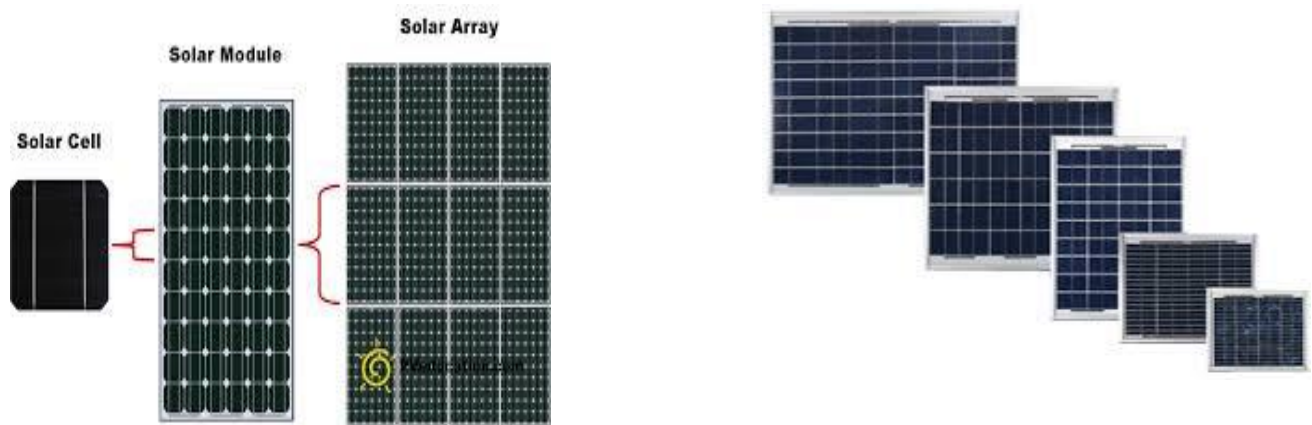


Fig.6.10 Solar Panel

6.2.2. Dust Sensor

This module is a dust sensing system based on the sensor GP2Y1010AU0F. It integrates an internal infrared emitting diode (IRED) to detect the reflected light of dust in air and generate an output voltage proportional to dust density so as to measure dust and smoke concentration.

- Measured object: Fine particle larger than $0.8\mu\text{m}$ in diameter
- Measurement range: $500\mu\text{g}/\text{m}^3$
- Output: Analog voltage
- Working voltage: $2.5\text{V}\sim 5.5\text{V}$
- Dimensions: $63.2\text{mm}\times 41.3\text{mm}$
- Fixed hole size: 2.0mm
- Air hole size: 9.0mm

Output characteristics

The output voltage of the module is proportional to dust density in the range of 0 to $0.5\text{mg}/\text{m}^3$,

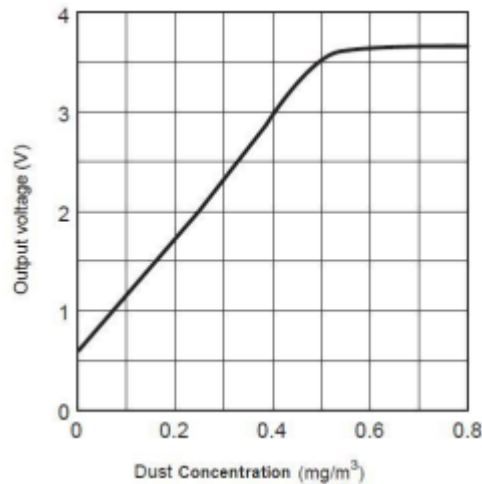


Fig 6.11 Output characteristics of voltage propotional to dust density

Control principle

- 1) Enable the internal infrared emitting diode by setting the pin ILED to HIGH.
- 2) Wait 0.28ms, then the external controller starts to sample the voltage from the pin AOUT of the module. Notes that the output wave will take 0.28ms to reach steady state after the internal infrared emitting diode is enabled.
- 3) There is a period of 0.04ms for sampling. When finished, set the pin ILED to LOW to disable the internal infrared emitting diode.
- 4) Calculate the dust concentration according to the relationship between output voltage and dust concentration. For more detailed information, please refer to the relative Demos. Note: The output voltage has been divided (see schematic), so that the voltage measurement should x 11 to get the actual voltage.

Applications

It is applied to detect of dust in the air, such as the applications of Air Purifier, Air Monitor and PM2.5 Detector.

6.2.3. LCD Display

Liquid crystal displays (LCDs) have materials which combine the properties of both liquids and crystals. Rather than having a melting point, they have a temperature

range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered form similar to a crystal.

An LCD consists of two glass panels, with the liquid crystal material sandwiched in between them. The inner surface of the glass plates is coated with transparent electrodes which define the character, symbols or patterns to be displayed. Polymeric layers are present in between the electrodes and the liquid crystal, which makes the liquid crystal molecules to maintain a defined orientation angle.

On each polariser is pasted outside the two glass panels. These polarisers would rotate the light rays passing through them to a definite angle, in a particular direction.

When the LCD is in the off state, light rays are rotated by the two polarisers and the liquid crystal, such that the light rays come out of the LCD without any orientation, and hence the LCD appears transparent.

When sufficient voltage is applied to the electrodes, the liquid crystal molecules would be aligned in a specific direction. The light rays passing through the LCD would be rotated by the polarisers, which would result in activating / highlighting the desired characters.

The LCDs are lightweight with only a few millimeters thickness. Since the LCD's consume less power, they are compatible with low power electronic circuits, and can be powered for long durations.

The LCDs don't generate light and so light is needed to read the display. By using backlighting, reading is possible in the dark. The LCD's have long life and a wide operating temperature range.

Spec:

- Correspond to high speed MPU interface (2MHz)
- 80 x 8-bit display RAM (80 Characters ax)
- 9,920-bit character generator ROM for a total of 240-character fonts. 208-character fonts (5 x 8 dots) 32-character fonts (5 x 10 dots)

- 64 x 8-bit character generator RAM 8-character generator RAM 8-character fonts (5 x 8 dots) 4 characters fonts (5 x 10 dots)
- Programmable duty cycles

Block Diagram:

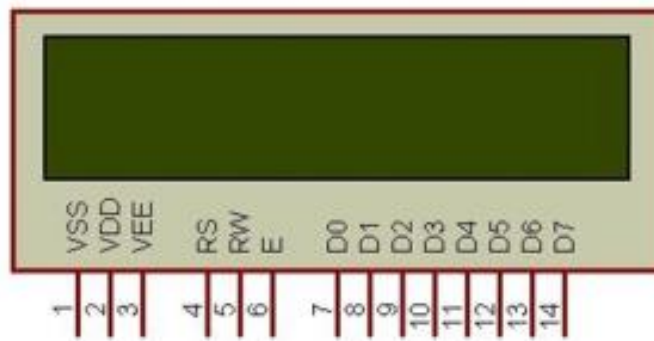


Fig.6.12 LCD Display

6.2.4. SMPS (switch-mode power supply)

The electronic power supply integrated with the switching regulator for converting the electrical power efficiently from one form to another form with desired characteristics is called as Switch-mode power supply. It is used to obtain regulated DC output voltage from unregulated AC or DC input voltage.

Switched mode power supplies are used to power a wide variety of equipment such as computers, sensitive electronics, battery-operated devices and other equipment requiring high efficiency.

Switched-mode power supplies are classified according to the type of input and output voltages. The four major categories are:

- AC to DC
- DC to DC
- DC to AC
- AC to AC

6.2.5 Relay

Relays are the primary protection as well as switching devices in most of the control processes or equipment regardless of whether they are electronic or electromechanical.

All the relays respond to one or more electrical quantities like voltage or current such that they open or close the contacts or circuits. A relay is a switching device as it works to isolate or change the state of an electric circuit from one state to another. These are found in all sorts of devices. Relays allow one circuit to switch over to a second circuit that can be completely separated from the first. There is no electrical connection inside the relay between the two circuits – the link is magnetic and mechanical only.

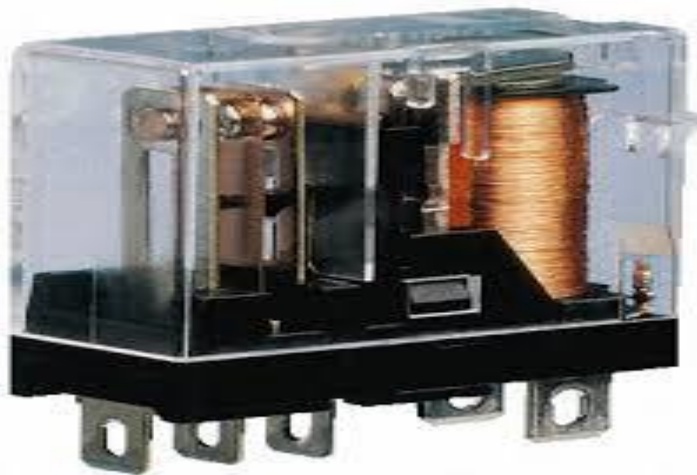


Fig.6.13 Relay

6.2.6. Voltage sensor

A voltage sensor is a sensor used to calculate and monitor the amount of voltage in an object. Voltage sensors can determine the AC voltage or DC voltage level. The input of this sensor is the voltage, whereas the output is the switches, analog voltage signal, a current signal, or an audible signal.

Sensors are devices that can sense or identify and react to certain types of electrical or optical signals. The implementation of a voltage sensor and current sensor

techniques have become an excellent choice for the conventional current and voltage measurement methods.

voltage sensor can determine, monitor, and measure the supply of voltage. It can measure the AC level and/or DC voltage level. The input to the voltage sensor is the voltage itself, and the output can be analog voltage signals, switches, audible signals, analog current levels, frequency, or even frequency-modulated outputs.



Fig.6.14 Voltage Sensor

6.2.7 12v Lead-Acid rechargeable battery

Lead acid batteries are the most commonly used type of battery in photovoltaic systems. Although lead acid batteries have a low energy density, only moderate efficiency and high maintenance requirements, they also have a long lifetime and low costs compared to other battery types. One of the singular advantages of lead acid batteries is that they are the most commonly used form of battery for most rechargeable battery applications (for example, in starting car engines), and therefore have a well-established established, mature technology base.

A lead acid battery consists of a negative electrode made of spongy or porous lead. The lead is porous to facilitate the formation and dissolution of lead. The positive electrode consists of lead oxide. Both electrodes are immersed in a electrolytic solution of sulfuric acid and water. In case the electrodes come into contact with each other through physical movement of the battery or through changes in thickness of the electrodes, an electrically insulating, but chemically permeable membrane separates the two electrodes. This membrane also prevents electrical shorting through the electrolyte. Lead acid batteries store energy by the reversible chemical reaction.



Fig.6.15 LEAD-ACID RECHARGEABLE BATTERY

6.3 AUTOMATION COMPONENTS AND SOFTWARE:

6.3.1. Arduino Nano

- Arduino Nano is a small, compatible open-source electronic development board based on an 8-bit AVR microcontroller. Two versions of this board are available, one is based on ATmega328p, and the other on Atmega168.
- Arduino Nano can perform some functions similar to other boards available in the market, however, it is smaller in size and is a right match for projects requiring less memory space and fewer GPIO pins to connect with.



Fig.6.16 Arduino Nano

- This unit features 14 digital pins which you can use to connect with external components, while 6 analog pins of 10-bit resolution each, 2 reset pins, and 6 power pins are integrated on the board.
- Like other Arduino boards, the operating voltage of this device is 5V, while input voltage ranges between 6V to 20V while the recommended input voltage ranges from 7V to 12V.
- The clock frequency of this unit is 16MHz which is used to generate a clock of a certain frequency using constant voltage.
- The board supports a USB interface and it uses a mini-USB port, unlike most Arduino boards that use the standard USB port. And there is no DC power jack included in this unit i.e., you cannot power the board from an external power supply.
- Plus, this device is bread-board friendly in nature means you can connect this unit with breadboards and make a range of electronic projects.



Fig.6.17 Arduino Nano Pin Diagram

- The flash memory is used to store the program and the flash memory of Atmega168 is 16KB (of which 2KB is used for the Bootloader) and the flash memory of Atmega328 is 32KB.
- Similarly, the EEPROM is 512KB and 1KB, and SRAM is 1KB and 2KB for Atmega168 and Atmega328 respectively.

- The Nano board is almost similar to the UNO board with the former smaller in size with no DC power jack.

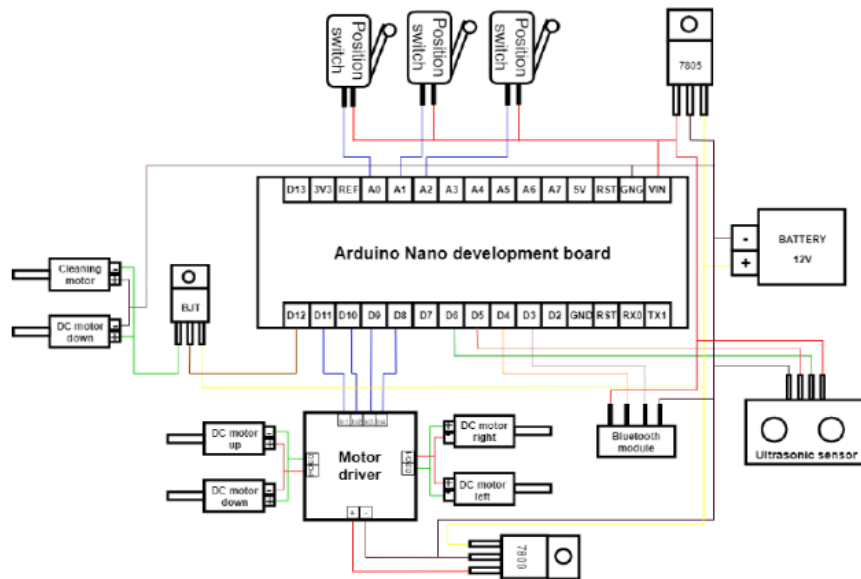


Figure 2. Schematic hardware of the designed SPCR.

Fig.6.18 Schematic Hardware of the Designed System

6.3.2. Proteus software

Proteus 8 is a best simulation software for various designs with microcontroller. It is mainly popular because of availability of almost all microcontrollers in it. So, it is a handy tool to test programs and embedded designs for electronics hobbyist. Can simulate programming of microcontroller in Proteus 8 Simulation Software. After simulating circuit in Proteus 8 Software can directly make PCB design.

Proteus is a Virtual System Modelling (VSM) that combines circuit simulation, animated components and microprocessor models to co-simulate the complete microcontroller-based designs. This is the perfect tool for engineers to test their microcontroller designs before constructing a physical prototype in real time. This program allows users to interact with the design using on-screen indicators and LED and LCD displays and, if attached to the PC, switches and buttons.

Proteus comes with extensive debugging features, single stepping and variable display for a neat design prior to hardware prototyping. Proteus is the program to use when we want to simulate the interaction between software running on a microcontroller and any analog or digital electronic device connected to it.

Proteus was initially created as a multiplatform (DOS, Windows, Unix) system utility, to manipulate text and binary files and to create CGI scripts. The language was later focused on Windows, by adding hundreds of specialized functions for: network and serial communication, database interrogation, system service creation, console applications, keyboard emulation, ISAPI scripting (for IIS). Most of these additional functions are only available in the Windows flavor of the interpreter, even though a Linux version is still available.

Proteus was designed to be practical (easy to use, efficient, complete), readable and consistent.

Its strongest points are:

- powerful string manipulation;
- comprehensibility of Proteus scripts;
- Availability of advanced data structures: arrays, queues (single or double), stacks, bit maps, sets, AVL trees.
- The language can be extended by adding user functions written in Proteus or DLLs created in C/C++.

Proteus has a fully functional, procedural approach; variables are untyped, do not need to be declared, can be local or public and can be passed by value or by reference; all the typical control structures are available (if-then-else; for-next; while-loop; repeat-until; switch-case); new functions can be defined and used as native functions.

Data types supported by Proteus are only three: integer numbers, floating point numbers and strings. Access to advanced data structures (files, arrays, queues, stacks, AVL trees, sets and so on) takes place by using handles, i.e., integer numbers returned by item creation functions.

Type declaration is unnecessary: variable type is determined by the function applied – Proteus converts on the fly every variable when needed and holds previous data renderings, to avoid performance degradation caused by repeated conversions.

There is no need to add parenthesis in expressions to determine the evaluation order, because the language is fully functional (there are no operators).

Proteus includes hundreds of functions for:

- accessing file system;
- sorting data;
- manipulating dates and strings;
- interacting with the user (console functions)
- Calculating logical and mathematical expressions.

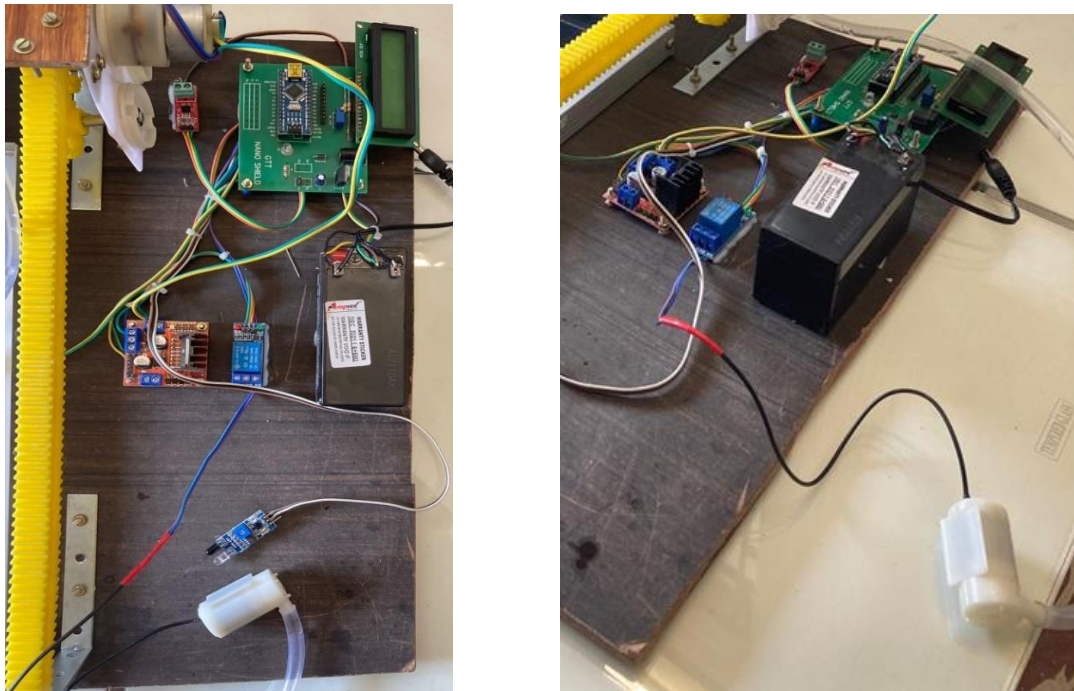


Fig.6.19 Components of the Designed System

6.4 HARDWARE SETUP

6.4.1 MCB interface to Switch Mode Power Supply (SMPS)

- MCB is a circuit breaker.
- MCB is used to take the input of 230V AC supply.
- This current from MCB is given as an input to the SMPS of 24V& 12V.
- The main function of MCB is to avoid the shorts circuits in the system.

6.4.2 Switch Mode Power Supply (SMPS 24V) interfaced with PLC

- SMPS is a device used to convert the input of 230V AC supply to 24V DC supply.
- This output of SMPS 24V DC is given as an input to the PLC.

6.4.3 Switch Mode Power Supply (SMPS12V) interfaced with other device

- This 12V SMPS output connection is given to the two 12V gear DC Motor and two 6V DC pumps.

6.4.4 PLC interfaced with various input & output

PLC is the commanding device for various input and output.

The PLC consist of two connection ports

Input Port

This input port has four different device input slots:

1. Limit switch 1
2. Limit switch 2
3. Start push button
4. Stop push button

Output Port

This output port has five different device output slots:

1. For motor reverse
2. For motor forward
3. Green working light
4. Red stop light
5. Green start light

6.5 WORKING OF THE SYSTEM

The cleaning unit moves on the central part of the panel in a back-and-forth motion. This results in mopping action on the solar panel cleaning the panels. This frame is also consisting of DC motors which will produce the rotational motion which is converted into linear motion through rack system. This action is controlled by signal generated by Arduino.

As soon as the gear motor starts moving, the pump gets actuated and the spraying action starts. The wiper mounted on the cleaning tool units also start moving in the forward direction. This entire cleaning tool is carried by the pinion which is guided by rack. Along the entire path, the water is spread on the solar panel it forces the dust to move in the direction of the motion of the cleaning unit and simultaneously the wiper wipes the panel finally flows it away at the edge of the panel.

Now the gear motors run in backward direction (anti clockwise). As soon as the motor is reversed the pumps gets off and the spraying action is stopped. Now the cleaning tool starts moving towards the initial position, the wiper fully wipes the panel without the water spraying. As the cleaning tool comes to the initial position the cycle completes and the process is stop.

Thus, the cleaning tool will be moving on the solar panel to clean for the new cycle and the process repeats.



Fig.6.20 Working Model.

CHAPTER 7

RESULT

As said in the problem description, how is dust reduces efficiency of the solar power plants and how effective is automatic cleaning system is better comparing to another systems. Below are the data which show how effectively the cleaning system works.

Formula to find efficiency of solar panel, $\text{Efficiency} = \frac{\text{Output Power in Watts}(P)}{\text{Input Power} \times \text{Area}(A)} \times 100$

A=Area of solar panel in m2, P = Power in watts [Voltage(V)×Current(I)]

Input Power = 1000 w/m2

Table.1 Efficiency of Solar Panel without Cleaning system

SL NO	DATE	Voltage (Volts)	Current (Amps)	Power (Watts)	Efficiency (%)
1	12-02-2022	9.65	0.2	1.93	2.23
2	13-02-2022	9.61	0.2	1.92	2.22
3	14-02-2022	9.57	0.2	1.91	2.22
4	15-02-2022	9.54	0.2	1.91	2.21

5	16-02-2022	9.48	0.2	1.90	2.19
6	17-02-2022	9.45	0.2	1.89	2.19
7	18-02-2022	9.41	0.2	1.88	2.18
8	19-02-2022	9.39	0.2	1.88	2.17
9	20-02-2022	9.26	0.2	1.85	2.14
10	21-02-2022	9.05	0.2	1.81	2.09
11	22-02-2022	8.94	0.2	1.79	2.07
12	23-02-2022	8.76	0.2	1.75	2.03
13	24-02-2022	8.61	0.2	1.72	1.99
14	25-02-2022	8.4	0.2	1.68	1.94
15	26-02-2022	8.26	0.2	1.65	1.91
16	27-02-2022	7.96	0.2	1.59	1.84

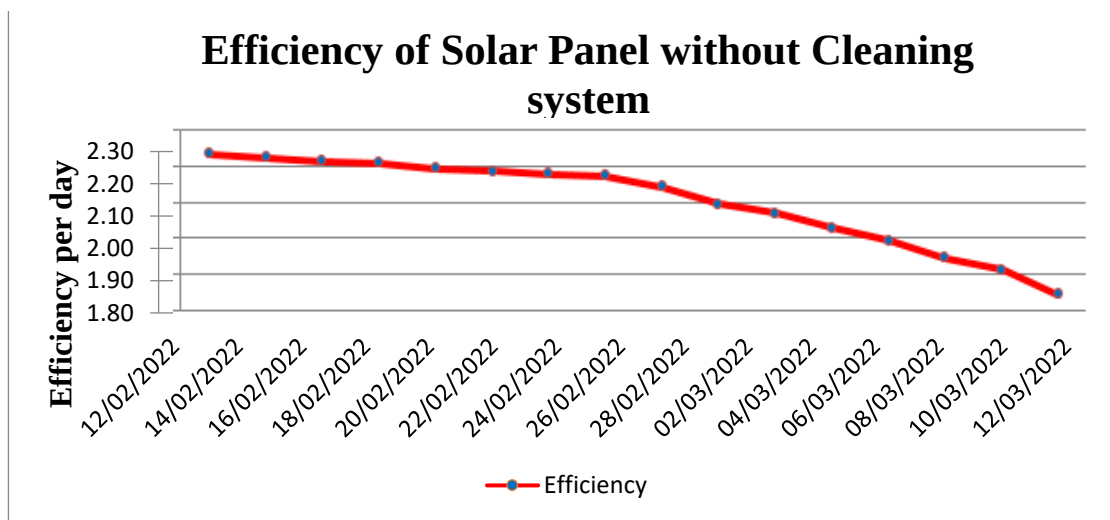


Fig.7.1 Efficiency of Solar Panel without cleaning system

The above graph shows how the efficiency of the panel goes on decreasing day by day due to dust accumulation. It was absorbed that there was drop of efficiency of 18% for 15 days of data collected.

Table.2 Efficiency of Solar Panel with Cleaning system

SL NO	DATE	Voltage (Volts)	Current (Amp)	Power (Watts)	Efficiency (%)
1	28-02-2022	9.52	0.2	1.90	2.20
5	01-03-2022	9.44	0.2	1.89	2.19
6	02-03-2022	9.4	0.2	1.88	2.18
7	03-03-2022	9.56	0.2	1.91	2.21
8	04-03-2022	9.51	0.2	1.90	2.20
9	05-03-2022	9.42	0.2	1.88	2.18
10	06-03-2022	9.59	0.2	1.92	2.22
11	07-03-2022	9.5	0.2	1.90	2.20
12	08-03-2022	9.45	0.2	1.89	2.19
13	09-03-2022	9.55	0.2	1.91	2.21
14	10-03-2022	9.5	0.2	1.90	2.20
15	11-03-2022	9.47	0.2	1.89	2.19
16	12-03-2022	9.6	0.2	1.92	2.22
17	13-03-2022	9.59	0.2	1.92	2.22
18	14-03-2022	9.5	0.2	1.90	2.20
19	15-03-2022	9.59	0.2	1.92	2.22
20	16-03-2022	9.54	0.2	1.91	2.21
21	17-03-2022	9.44	0.2	1.89	2.19
22	18-03-2022	9.61	0.2	1.92	2.22
23	19-03-2022	9.59	0.2	1.92	2.22
24	20-03-2022	9.5	0.2	1.90	2.20
25	21-03-2022	9.65	0.2	1.93	2.23
26	22-03-2022	9.61	0.2	1.92	2.22
27	23-03-2022	9.5	0.2	1.90	2.20
28	24-03-2022	9.65	0.2	1.93	2.23

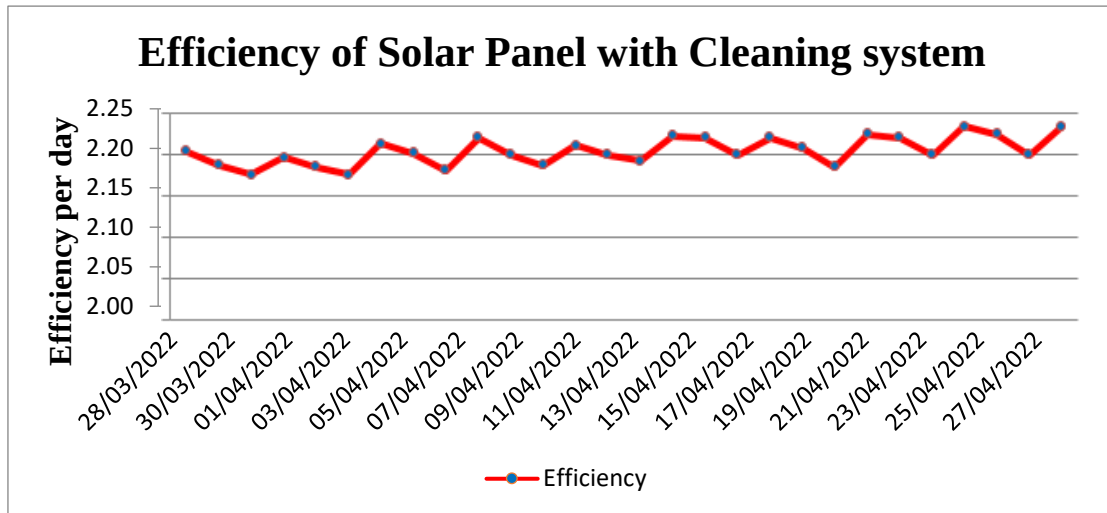


Fig.7.2 Efficiency of Solar Panel with Cleaning system

The above graph shows how efficiency of the solar panel when the automatic cleaning system was installed. The RTC was set for every third days, hence the system cleaned the panel for every third day and there is gain in the efficiency of the panel.

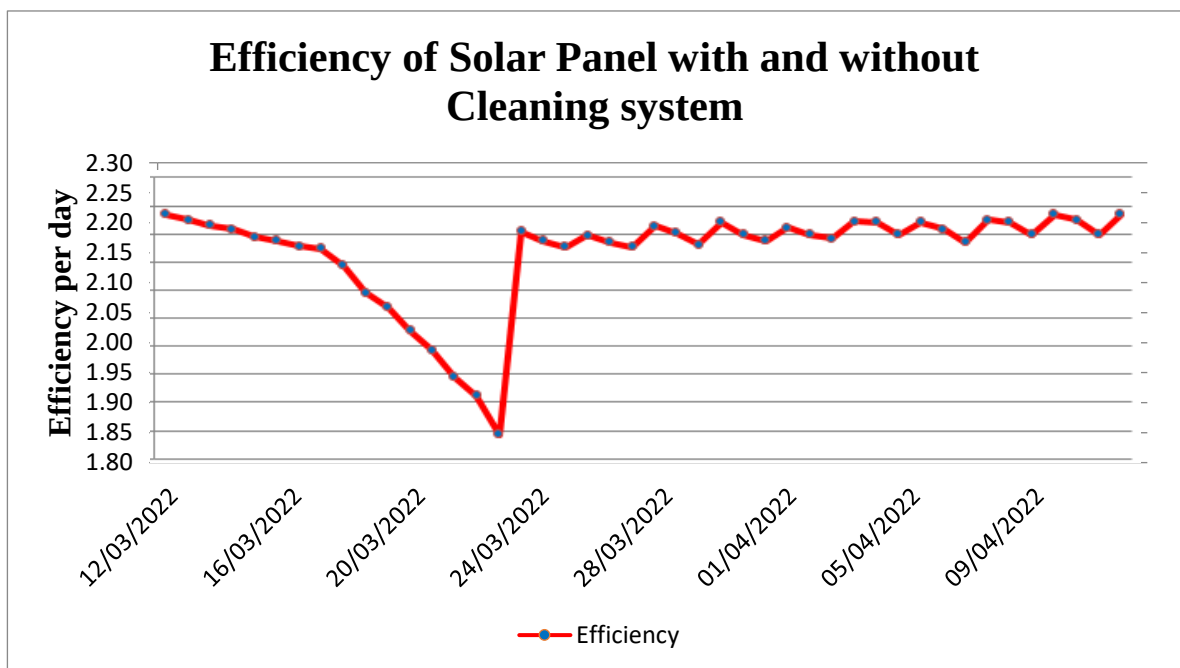


Fig.7.3 Efficiency of Solar Panel with and without cleaning system

The above graph helps us to understand how useful is to cleaning system to improve the efficiency of the solar panel. From the above data it was clear that there are 18% increases in the efficiency.

CHAPTER 8

ADVANTAGES AND DISADVANTAGES

8.1 ADVANTAGES:

- Increases efficiency of solar plate.
- Sometime dust or other particles remains long time on a solar panel, so it damages the aluminium strip of solar plate. So, we avoid these damages by this system.
- Increases the gain as much as 5 to 30% in output from your solar panels.
- Eliminate build-up of dirt and debris and potential damage to solar panels.
- Automatic self-cleaning mechanism that can be attached to solar panels and operated without human operation.
- Minimise the cost of cleaning as compared to manual.

- Remote control is possible.
- The entire plant can be handled by using single PLC system.

8.2 DISADVANTAGES:

- “Wiper Blade” which consists of a rubber band would need to be changed.
- Needs to be scaled for a larger project (ex: increase the torque of the motor).
- To take care of cleaning water, to avoid nozzles blockages.
- Skilled labour is required to handle the system

CHAPTER 9

CONCLUSION AND SCOPE OF THE PROJECT

9.1 CONCLUSION

The main conclusions can be summarized as: The losses of the output power of the fixed solar panel at a tilt angle (35) is about 25% of the rated yield and can be higher depending on the dust form. The dirt and bird drop make a hotspot in the panel, and it can make temporary fail in the panel. Dry cleaning can' not remove all the dirt on the surface of the solar panel, but it is able to remove the outer layers of the dust. Cleaning solar panel with water increases the cleaning efficiency by removing majority of the dirt deposited on the panel. No external powers are required as the self- cleaning system takes its power from the battery of the solar panel. This device is made up of lightweight material, so the power consumed is low. Comparing the costs of cleaning by Manual operation and Automatic operation the cost for automatic cleaning is proved to be more economic and significantly less cumbersome particularly in systems having large number of solar panels. Also, frequent periodic cleaning ensures that the solar panel works with a good transmittance consistently at all times.

9.2 FUTURE SCOPE OF THE PROJECT

1. Wireless transmission: - the movement of the tool which is done by PLC can be done wireless by using radio frequency which will reduce the cost involved in installing the system and also the complexity in maintaining the system will be reduced.
2. Wireless monitoring: - the present system which is monitored by SCADA through interfacing with PLC by wiring can also be done wireless.
3. Replacing the rack and pinion mechanism with other type of mechanism like track system for bigger power plants.
4. Interfacing with VFD (variable-frequency drive) drives for optimizing the power consumed by the system.
5. Using LDR sensor, it helps to sense amount of dust on panel and cleans the module automatically.

CHAPTER 10

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