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DESIGN AND MANUFACTURING OF AUTOMATIC SOLAR PANEL CLEANING MECHANISM

HRUSHIKESH GADHAVE[1], SHASHANK KEERTIWAR[2], GEETA KOLHE[3], DIPIKA CHAVAN[4], PROF. CHETAN KOLAMBE[5]

Student, Dept. of Mechanical Engineering, Anantrao Pawar Collage Of Engineering & Research ,Pune, Maharashtra, India[1-4]

Assistant Professor, Dept. of Mechanical Engineering, Anantrao Pawar Collage Of Engineering & Research ,Pune, Maharashtra, India[5]

Abstract*:* With rising electricity bills and concerns about the environmental effect of fossil fuels, the use of environmentally friendly energy sources such as solar power is on the rise. Arrays of photovoltaic (PV) panels are the most common way to harvest solar energy. The accumulation of dust and debris on even one panel in an array affects the array's energy generation efficiency significantly, emphasising the need of keeping the panels' surface as clean as possible. Our project's purpose is to develop an automated solar panel cleaner that will aid in the cleaning of panels for both residential and solar power plants. In particular, we aimed to develop a device that boosts a filthy panel's maximum power output by 15% to make up for the lost power owing to dust and contaminated panels.

I. INTRODUCTION

According to Indian Renewable energy Industry Report (September 2021) Indian energy renewable sector is the fourth most attractive renewable energy market in the world. India was ranked fourth in wind power, fifth in solar power and fourth in renewable power installed capacity, as of 2020. From this we come to know that, Solar power in India is a fast-developing industry as part of the renewable energy in India. The solar energy available in a single year exceeds the possible energy output of all of the fossil fuel energy reserves in India. With about 300 clear and sunny days in a year, the calculated solar energy incidence on India’s land area is about 5,000 trillion kilo-watt hours per year. The daily average solar-power-plant generation capacity in India is 0.30 kWh per m2 of used land area, equivalent to 1,400–1,800 peak (rated) capacity operating hours in a year with available, commercially-proven technology.

There are more than 40 Major Solar power plants in India, which generate at least 10 MW of power. In a recently released report of the Ministry of New and Renewable Energy (MNRE), Government of India, Rajasthan has overtaken Karnataka to rank first in the country with an installed capacity of 7737.95 MW of solar power.
Single solar module can produce only a limited amount of power; most installations contain multiple modules adding voltages or current to the wiring and PV system. A photovoltaic system typically includes an array of photovoltaic modules, an inverter, a battery pack for energy storage, charge controller, interconnection wiring, circuit breakers, fuses, disconnect switches, voltage meters, and optionally a solar tracking mechanism. Equipment is carefully selected to optimize output, energy storage, reduce power loss during power transmission, and conversion from direct current to alternating current.

Several companies have begun embedding electronics into PV modules. This enables performing MPPT for each module individually, and the measurement of performance data for monitoring and fault detection at module level. Some of these solutions make use of power optimizers, a DC-to-AC converter technology developed to maximize the power harvest from solar photovoltaic systems. As of about 2010, such electronics can also compensate for shading effects, wherein a

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shadow falling across a section of a module causes the electrical output of one or more strings of cells in the module to fall to zero, but not having the output of the entire module fall to zero.

II. LITERATURE SERVEY

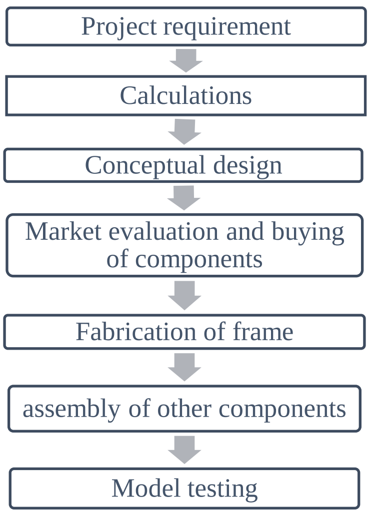
Ram Jatan Yadav, Lakshay Saini, Devashish, Rishabh Tomar, Vipul Rana "Domestic Solar Panel Cleaning System and effect of Environmental Dust in PV Modules"
This paper describes about the various studies revolving around how dirt and dust affect the performance of solar panels depending upon different regions, as different areas have different soil compositions and how they are different from one another. Due to the inconsistencies in cleaning especially in region where rain is not the most convenient option for cleaning. On continuous using of solar panels, a layer of accumulated dust particles is settled on the surface of solar panels or PV panels which affect the result of decreasing in efficiency by 50 %. By cleaning on regular intervals, it decreases this soil loss. Various data have been collected which shows the importance of domestic solar panel cleaning for future generation.

Nasib Khadka, Aayush Bista, Binamra Adhikari, Diwakar Bista, and Ashish Shrestha"Smart Solar Photovoltaic Panel Cleaning System"
This paper presents the design and fabrication process of a prototype along with its testing on a demonstration photovoltaic module; furthermore, depicting the implementation of the developed model on large-scale solar farms. The prototype of this system comprises of a cleaning robot and a cloud interface: the cleaning robot is mobile, and able to clean the entire solar array back and forth, with its separately driven cleaning rotatory brush; whereas, the cloud interface is a human-machine interface featuring the distant monitoring and control of the robot.

Sharvari Nikesh Ghate, Karan Rajendra Sali, Avinash Sureshprasad Yadav, Namita Sandeep Neman, Jagdish Chahan "Design and fabrication of Automatic Solar Panel Cleaning System"
This paper describes about their study of effects of change in efficiency of PV modules due to the accumulation of different dust particles found in different regions, factors governing for the decrease in efficiency accounts a lot due to soiling and developing an automated mechanism for cleaning. Labour-based cleaning methods for PV modules are expensive and uses a large amount of water. This prototype includes DC motors controlled by a drive unit that moves a cleaning head horizontally with or without using a spraying system. This results in an increase in efficiency of overall PV modules, the amount of renewable energy harnessed is more, less water usage and less water usage.

III. METHODOLOGY

DESIGN METHODOLOGY:



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CALCULATIONS:

In these calculations the mass of the entire system was considered as 15 kg. Therefore, the calculations are different in theoretical and actual.

To calculate force

For calculation of force, we require mass and acceleration.

Considering factor of safety, we increase the weight by multiplying 1.5 *15 kg

i.e., 22.5 kg

Using equation, F = m×a,

Where F = force

m = mass of the body = 22.5 kg

a = acceleration = 2.778 m/s

therefore, F = m×a

F = 22.5 * 2.778

F = 62.505 Newtons

Torque calculations

Now to calculate torque required, we need the total distance from start point to end point of the solar panel, the force the angle between the force vector and panel.

Using equation,

Ʈ = rFsinθ

Therefore, Ʈ = rFsinθ

Ʈ = 1.6764× 62.505[sin90]

Ʈ =104.783 Nm.

Calculation of Power

Now to calculate, power required we need total distance of horizontal panel and torque.

Using equation,

$P = \frac{2\pi N\tau}{60}$

$N = \frac{total\ distance}{distance\ covered\ in\ one\ rotation}$

Where total distance is the horizontal distance of panel i.e., 1676.4mm

Distance covered in one rotation is 314.16mm i.e., the circumference of the outer roller that is 100mm diameter, using πD formula we get the circumference as 314.16. circumference is nothing but distance covered in one rotation.

$= \frac{1676.4}{314.16}$

N = 5.37

Ʈ = torque

Therefore, $P = \frac{2\pi N\tau}{60}$

$P = \frac{2\pi * 5.37 * 104.783}{60}$

P = 58.92 watts

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ACTUAL CALCULATIONS

To calculate force

For calculation of force, we require mass and acceleration.

By using $w = m \times g$

We have total weight up to 7 kg(total weight is nothing but weight of each component in the system).

Considering factor of safety, we increase the weight by multiplying 1.5 × 7kg

i.e., 10.5 kg

Using equation, F = m×a,

Where F = force

m = mass of the body = 10.5kg

a = acceleration = 2.778 m/s

therefore, F = m×a

F = 10.5 ×2.778

F= 29.17 Newtons

Torque calculations

Now to calculate torque required, we need the total distance from start point to end point of the solar panel, the force the angle between the force vector and panel.

Using equation,

Ʈ = rFsinθ

Where Ʈ = torque required

r = distance from starting point of panel to end point of panel = 1.6764 m

F = force = 62.505 N

θ = angle between the force vector and the panel = 90º

Therefore, Ʈ = rFsinθ

Ʈ = 1.6764 ×29.17[sin90]

Ʈ = 48.90 Nm.

Calculation of Power

Now to calculate, power required we need total distance of horizontal panel and torque.

Using equation,

$P = \frac{2\pi N\tau}{60}$

Where P = power

N = number of rotations

$N = \frac{total\ distance}{distance\ covered\ in\ one\ rotation}$

Where total distance is the horizontal distance of panel i.e., 1676.4mm

Distance covered in one rotation is 314.16mm i.e., the circumference of the outer roller that is 100mm diameter, using πD formula we get the circumference as 314.16. circumference is nothing but distance covered in one rotation.

$= \frac{1676.4}{314.16}$

N = 5.37

Ʈ = torque

Therefore, $P = \frac{2\pi N\tau}{60}$

$P = \frac{2\pi \times 5.37 \times 48.90}{60}$

P = 27.49 watts

DC MOTOR:

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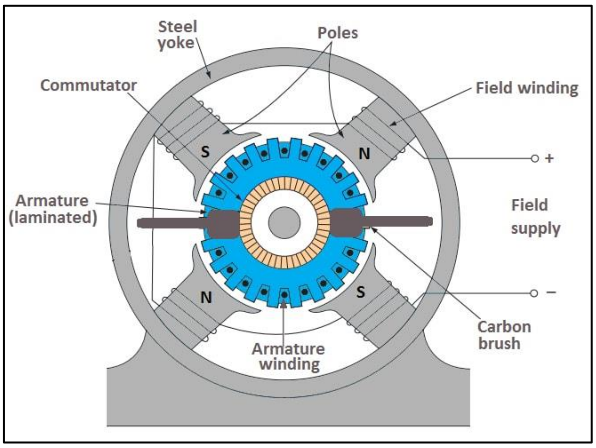

Without motor the movement of the mechanism is not possible, so motor is very useful in this mechanism.in this mechanism two different motors have been used according to their use.

Different Parts of a DC Motor.

A DC motor is composed of the following main parts:

Armature or Rotor

The armature of a DC motor is a cylinder of magnetic laminations that are insulated from one another. The armature is perpendicular to the axis of the cylinder. The armature is a rotating part that rotates on its axis and is separated from the field coil by an air gap.

Field Coil or Stator

A DC motor field coil is a non-moving part on which winding is wound to produce a magnetic field. This electro-magnet has a cylindrical cavity between its poles.

Commutator and Brushes

Commutator

The commutator of a DC motor is a cylindrical structure that is made of copper segments stacked together but insulated from each other using mica. The primary function of a commutator is to supply electrical current to the armature winding.

Brushes

The brushes of a DC motor are made with graphite and carbon structure. These brushes conduct electric current from the external circuit to the rotating commutator. Hence, we come to understand that the commutator and the brush unit are concerned with transmitting the power from the static electrical circuit to the mechanically rotating region or the rotor.

Working principle of DC motor

When kept in a magnetic field, a current-carrying conductor gains torque and develops a tendency to move. In short, when electric fields and magnetic fields interact, a mechanical force arises. This is the principle on which the DC motors work.

DC Motor Working

In the previous section, we discussed the various components of a DC motor. Now, using this knowledge let us understand the working of DC motors.

A magnetic field arises in the air gap when the field coil of the DC motor is energized. The created magnetic field is in the direction of the radii of the armature. The magnetic field enters the armature from the North Pole side of the field coil and "exits" the armature from the field coil's South Pole side. The conductors located on the other pole are subjected to a force of the same intensity but in the opposite direction. These two opposing forces create a torque that causes the motor armature to rotate.

1. For rotation of the roller brush Johnson 200rpm is used considering its high rpm which helps the roller brush to clean the panel at high speed.

Here are some of its specifications

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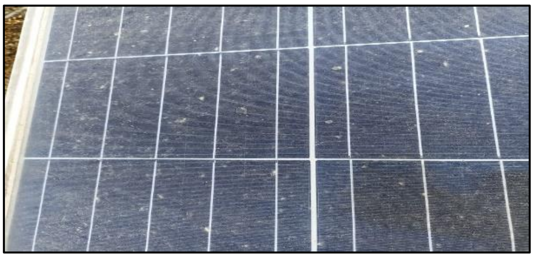
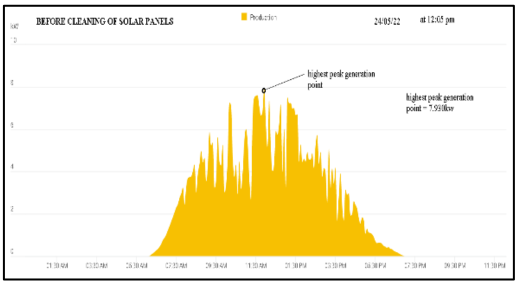
IV. RESULT

CALCULATIONS FOR EFFICIENCY OF A SINGLE PANEL

BEFORE CLEANING OF PANEL

On 24TH of May at 12:05pm the panels were dirty as shown in below figure and the readings of this are shown in the graph





Total number of panels = 31 numbers

total generation on 24th may at 12:05pm= 7.930kw

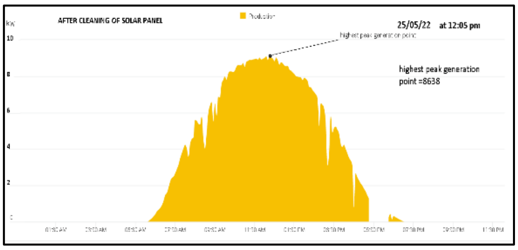
For calculation of single panel power generation = $\frac{total\ generation\ at\ 12{:}05pm}{no\ of\ panel}$

$= \frac{7.930}{31}$

= 0.255 kw

AFTER CLEANING OF PANEL

On 25TH of May at 11:45 am the panels were cleaned using the mechanism and after cleaning of solar panel the power generation is shown in below graph



Total number of panels = 31 numbers

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total generation on 25th may at 12:05pm= 8.638kw

For calculation of single panel power generation = $\frac{total\ generation\ at\ 12{:}05pm}{no\ of\ panel}$

$= \frac{8.638}{31}$

$= 0.279$ kw

Difference between before cleaning and after cleaning of solar panel = 0.279-0.255

= 0.024kw

Efficiency of the panel = $\frac{0.279-0.255}{0.279} \times 100$

= 8.60%

Hence the efficiency of the single solar panel is increased by 8.60%.

V. Conclusion

The main goal of this work is to develop a cleaning system which requires least human effort. To provide a less costly solar panel cleaning system that would be helpful for a huge solar plant as well as a household solar panel. From the above graphs it is found that the value of efficiency is maximum in case of solar panel without dust. So, it is concluded that as we clean the dust from the surface of the solar panel the efficiency of the solar panel increased by8.60% slightly recovering the efficiency losses due to environmental factors.

VI. FUTURE WORK

In this project there is a great scope to modify it in different ways like increasing its operation by using surface vacuum cleansers and spray of water.

- This system can be modified by sensors.
- The power supply from the panel itself can be used to supply the mechanism itself.
- It can be controlled by using remote controllers for necessary cleaning actions.
- It can also be operated using mobile phone applications from longer distances after feeding the suitable program.

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