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Automatic Solar Panel Cleaning Mechanism

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Abstract*:* *With increasing cost of electricity and the environmental impact of fossil fuels, implementation of renewable and nonconventional energy sources like solar power are rising. The best method to harness solar power is with arrays made up of solar panels. Because of the accumulation of dust, leaves, soil, and other material on even any one of the photo voltaic panels in an array reduces their efficiency to generate energy considerably and thus highlights the need to keep the panels' surface as clean as possible. The motive of our project is to create an automated solar panel cleaning mechanism that will address the impact of soiling, dirt collection on commercial photovoltaic solar farms where manual cleaning is not feasible. We hoped to create a device that would eventually increase the power output of a soiled panel. (recovering the amount of power lost).Furthermore, autonomous cleaning robots are only economical or viable on a larger scale because ofboth installation costs and the parts used for designing it are custom made according the requirements of the user.*

Key Word*:* photovoltaic (PV) panels, *automation,, Arduino uno, ,brushes, linear actuator, rack and pinion*

I. Introduction

Solar industry is growing worldwide, due to its economic, technological as well as environmental advantages. The Photo voltaic conversion efficiency ranges from 10 to 15% in commercial level. However, the outdoor installed Photovoltaic modules efficiency may reduce by 10 to 28%. The reduction in the effectiveness of these PV cells refers to the losses in the inverter, wiring and dust pollution. Any particulate matter that spreads in the air contains soil and dust particle, fog, smoke, dust and even leaves of trees etc. Dust consists of substances like sand, soil, bacteria, smokefrom factories, forest fires, pollen etc. They also include in them suspended solid particles that stay in the air for long period of time. These suspended particles can be transferred with wind for long distances. The areas which have high dust concentration levels leads to the significant losses due to dust pollution in the generation of power. Many studies had shown that the airborne dust deposition on the photovoltaic modules leads to the decrease in the transmittance of cell glazing. It also results in a degradation of solar conversion efficiency of Photo Voltaic modules. The dust deposition on the outdoor PV studies focused mainly on the glazing transparency performance. Ref. studied the PV array output in a city in Saudi Arabia. The results indicated that a 35% reduction in energy output observed duringthe panels exposure to outdoor conditions for about eight months. In the United Arab Emirates, El-Nashar investigated that the dust accumulation impact over the solar collectors' performance for different periods. The study shows that there is a monthly glass transmissivity decline rate between 10% in summer season compared to the 6% inwinter. In Iraq along with the formerly mentioned countries, Reference studies shows the impact of the stringent environmental conditions on the heliostat mirrors of CSP plant. The study also revealed that primarily factor was the dust that accumulated over the heliostats.

Cleaning of the solar panels is not always as straightforward as it might look. To begin with, there is a problem of accessibility. Due to the fact that solar panels are usually situated on dangerous and difficult to reach areas, it mightbe hard to clean them manually as it can even be fatal for manual cleaning process. It also takes time to do it safely. Secondly, cleaning a solar panel only once across a year may not have a very significant impact on the annual energy yield for the simple reason that dirt/dust stacks up again and again in a short period of time making the difference negligible. Especially if you need to contract someone to manually clean the panel for you, it may just not be economical. whereas, leaving panels uncleaned might not be a good idea, as soiling can lead to permanent damage of the glass limiting the lifespan of the

installation and the photo voltaic panels.

Components of the system:

- Solar panel – 90 watt (photovoltaic) solar panel.
- Mild steel frame - It is a structural support for the complete installation of solar panels and the automated cleaning mechanism. It provides the necessary stiffness and strength in order to resist the internal forces (vertical forces of gravity and lateral forces due to wind and earthquakes) and guide them safely to the ground providing the necessary strength and stiffness.
- Rack and pinion- It is a type of linear actuator that consists a circular gear (the pinion) that engages with a linear gear (the *rack*), which operates to translate rotational motion into linear motion. Driving the pinion into rotation causes the rack to be driven linearly and vice versa driving the rack linearly would cause the pinion to be driven intoa rotation
- Gear wheel – They are used to move the robot in different axes, they move across the length and breadth of the system to efficiently clean it.
- Brushes – Generally nylon solar panel cleaning brushes are used. The bristles of brushes are designed such that it does not cause any scratching or damage to the solar panels.
- Arduino Uno- It is a microcontroller board based on 8-bit ATmega328P microcontroller. Along with ATmega328P,it has some other components such as voltage regulator, crystal oscillator, serial communication etc. to support the Arduino. Arduino Uno also has 14 digital input/output pins (out of which 6 can be used as PWM outputs), 6 analogue input pins, a USB connection, A Power barrel jack, an ICSP header and a reset button.
- Dc Motor- Generally a DC motor with right angled drive reduction gearbox is used. It is ideal for robot or toy vehicle construction. Light weight plastic construction gearbox metal motor rated at 3-6VDC and gear can fit to the left or right of the gearbox and motor can be run in both forward and reverse direction thus enabling the robot to move across the system
- Battery / power source – As the motors selected were DC motors, and a high speed motor needs 24 volts to operate at its rated speed and the other motors needs 12 volts, two 12 volts batteries are needed to run the system.
- Sensors and signal conditioning circuit - The robot will have 2 limit switches, 2 proximity sensors and an encoder, which are located on the frame. It would give an indication for the frame position on the array so that the microcontroller i.e. Arduino can decide whether it should stop or start the cleaning process or to keep movingto the end of the array. Limit switch 1 and 2 are located in a frame, to determine if the brush is located atstart position or end position in Y-axis. Whereas the Proximity sensors are located on the frame, to determine if the frame reached to the end of the array in the X-axis thus with the help of these sensors we can determine the actual position of the brushes and frame and providing these information to the controller would thereafter send instructions about the cleaning to be done.
- Data logger – It is used for storing or recording the values during the experiment

Problem definition:

Solar panels work by allowing the light into the solar cells or photo voltaic cells. More the amount of light hitting a panel, more would be the power generated. The solar panels are usually fixed at an angle to receive maximum sunlight and Due to this upward angle of panels, they are more prone to bird droppings, leaves and dust accumulation and also build-up of moss and dirt that does not wash off with just rain. This in turn reduces the amount of sunlight hitting the panel and reduces its output to a great extent. Also the projected energy figures claimed by solar panel manufacturers and installers are based on the optimum performance of clean solar panels with maximum light hitting panels, Whereas this accumulated dirt can adversely affect the solar panel's ability to meet those projections. Hence, it is important to clean panels in order to protect and maintain your investment as soiling and dirt accumulation for long period of time can in turn damage the solar panels. Regular cleaning of this panels will also help you to make the most of the government feed-in tariff.

Objectives:

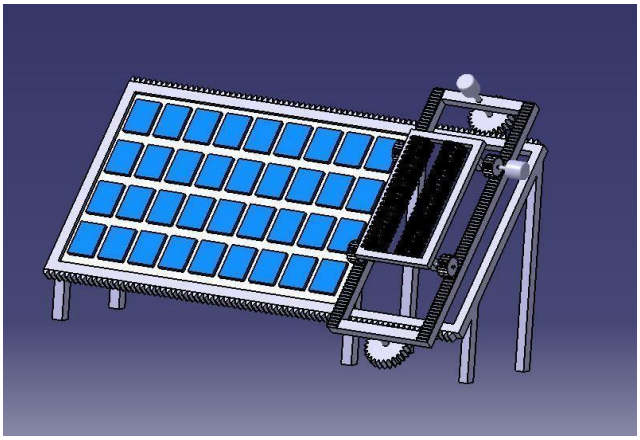
In our project we introduced the idea of robot for cleaning of solar panels, specialized to clean solar cells from dirt accumulation as well as it reduces the power losses occurring due to the constant accumulation of dirt and dust. Solar panel cleaning robot can be used without any human intervention to speed up the work in the large Photo voltaic solar farms. The robot moves in the tracks with the help of sensors and microcontroller that are mounted on the solar panel structure.

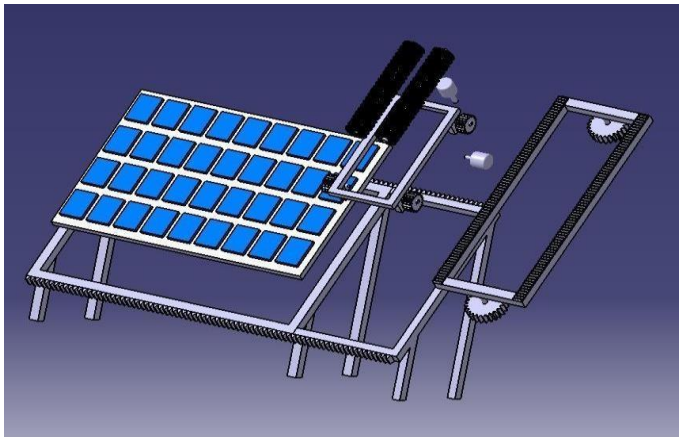
II. Literature Survey

Sr.no.	Author	Title	Conclusion
1.	Mohammad Abu-Naser	Solar Panels Cleaning Frequency for Maximum Financial Profit	average daily loss in solar conversion efficiency could be as high as 0.55%
2.	Ali Hasan Shah, Ahmed Hassan , Mohammad Shakeel Laghari and Abdulrahman Alraeesi	The Influence of leaning Frequency of Photovoltaic Modules on Power Losses in the Desert Climate	Average radiation penetration differences of 10% and 15% were observed between a daily clean glass module and the modules that kept dusty for 10 days and 20 days, respectively. The drop in radiation substantially increased to 19% and 32% for modules that kept dusty for 30 days and 90 days
3.	ATHAR HUSSAIN, ANKIT BATRA, RUPENDRA PACHURI	An Experimental study on effect of dust on power loss in solar photo voltaic module.	A detailed investigation on air dust particles effect on photo voltaic model in which it can be seen that in desert area, the accumulation of dust on PV panel surface is very high. The reduction in solar efficiency due to dust on PV panel is approximately 40 %.
4.	P.A. patil , jaydeep bagi,Mahesh wagh	A review on cleaning mechanism of solar panel photovoltaic cell	The study shows that a brush type solar panel could be ideal as it requires no water or little water for removal of dust.
5	World academy of science , engineering and technology	National renewable library	It states that the accumulation of dust over the solar panels can lead to losing almost 25% of energy output as compared to clear solar panels

III. Design

CAD model of proposed system:





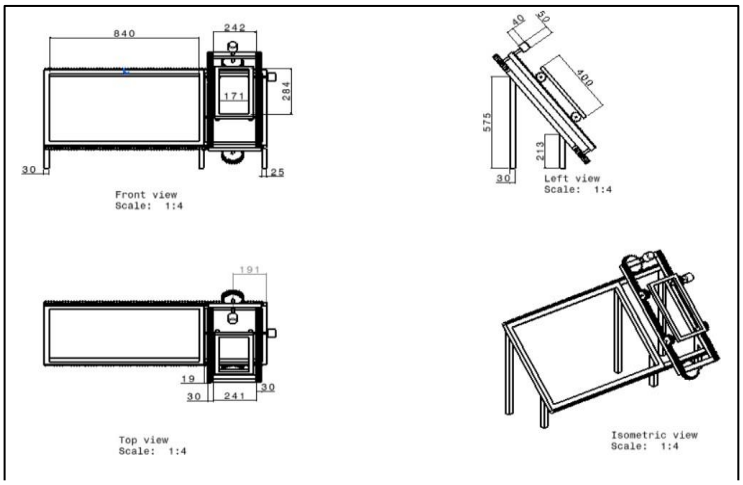
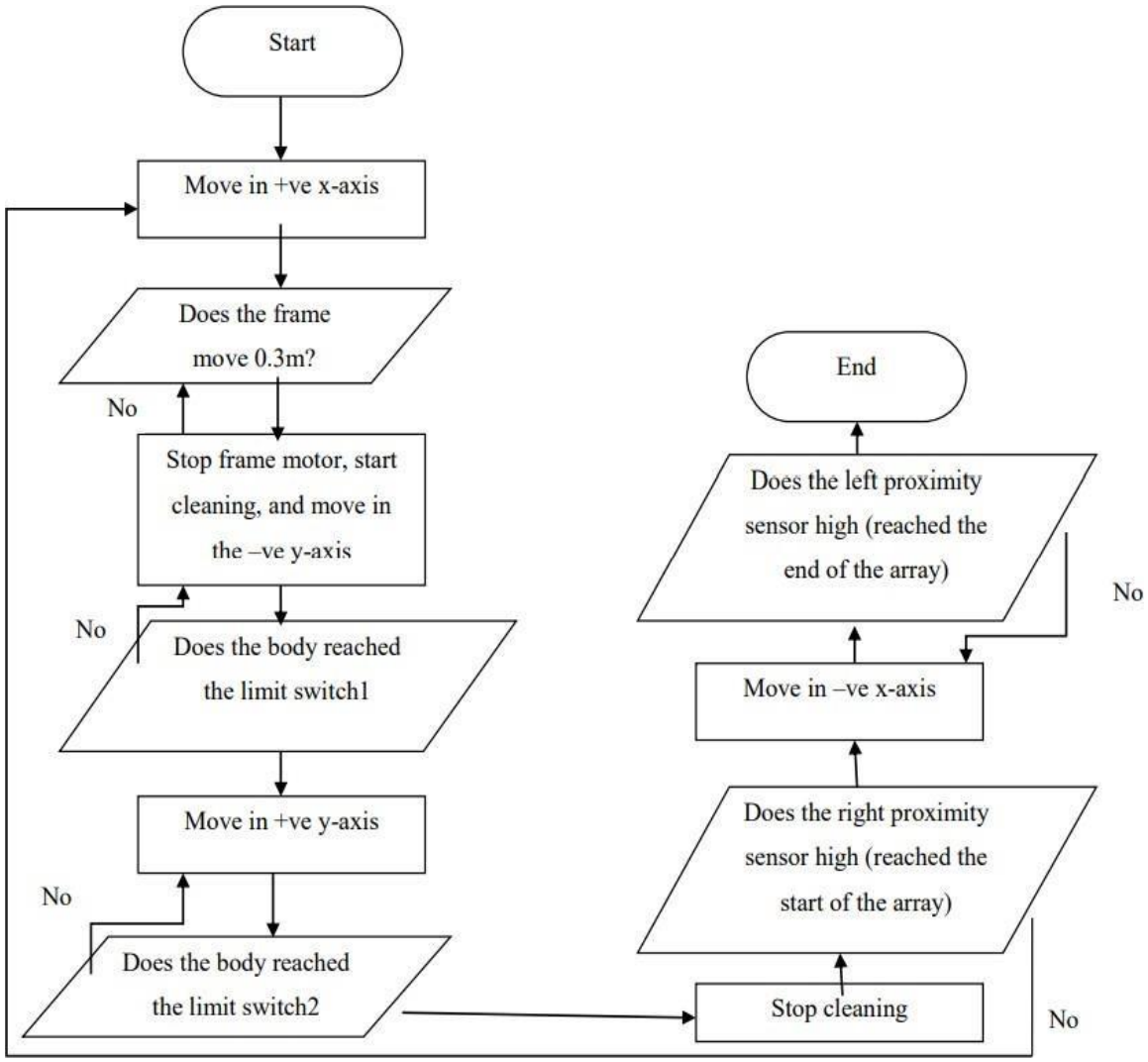


Fig. Drafting of cad model

. Process Flow Chart

Process flow chart is one of the easiest way that show casts how the system would work from the beginning tothe end and how it would follow the commands and its sequence with which it would follow them.



Calculations:

Rack and Pinion Design:
Its design procedure is same as spur gear procedure

Lets consider 10 Kg load is to be lifted by the bench-press. So, F= 10 X 9.81 = 100N
So, the torque transmitted to pinion is given as T =F * r
= 100* 0.035
= 3.5 Nm
M.S material for gear and pinion

For pinion (S_{ut} = 260 N/mm^2) For gear (S_{ut} =260 N/mm^2)

Factor of safety = 1

Considering 20^0 full depth involute system 8m<b<12m
Minimum Z_p = 17 for $\beta = 20^0$ $Z_g = 1 * Z_p$
$Z_p = Z_g$ =17 ..... practically

Beam strength:

$\sigma_{bp} = \sigma_{bg} = (S_{ut})_p / 3 = 260 / 3 =$ 86.66 N/mm^2 lewis form factor,
$Y_g = Y_p = 0.484 - 2.87/Z_p = 0.484 - 2.87/17 = 0.315$

P = 2ΠNT/ 60
= 2*3.14*3.5*30 /60
= 10.99 W
Now, we consider gear ratio as $G = d_p / d_g = N_g / N_p = Z_p / Z_g$
Here rack is acting as gear and pinion. Gear ratio is **1**
Because, N_g = 30 ; N_p = 30

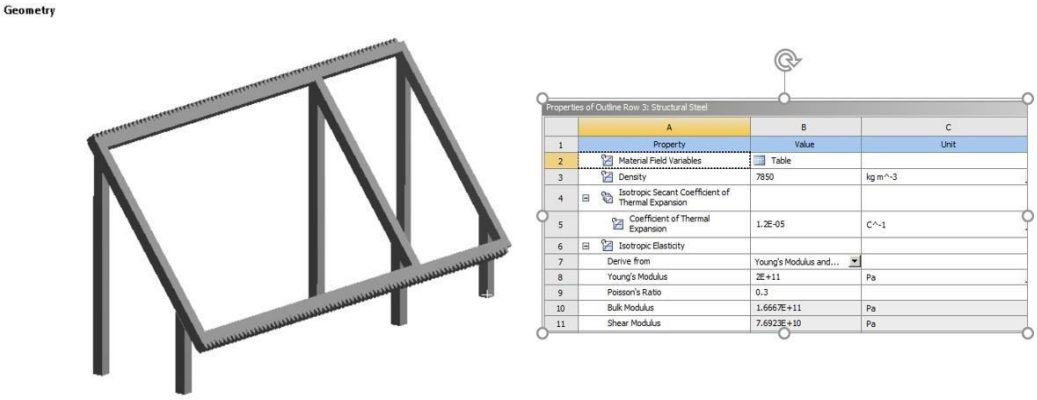
Power transmitted = 10.99 W

So, $(\sigma_{bg} * Y_g) = (\sigma_{bp} * Y_p) = (86.66 * 0.315)$
$=27.297\ N/mm^2$ $F_b = (\sigma_b)_p * Y_p * m\ b$
= 27.297*10m*m
= 272.97 m^2
Wear strength is calculated as

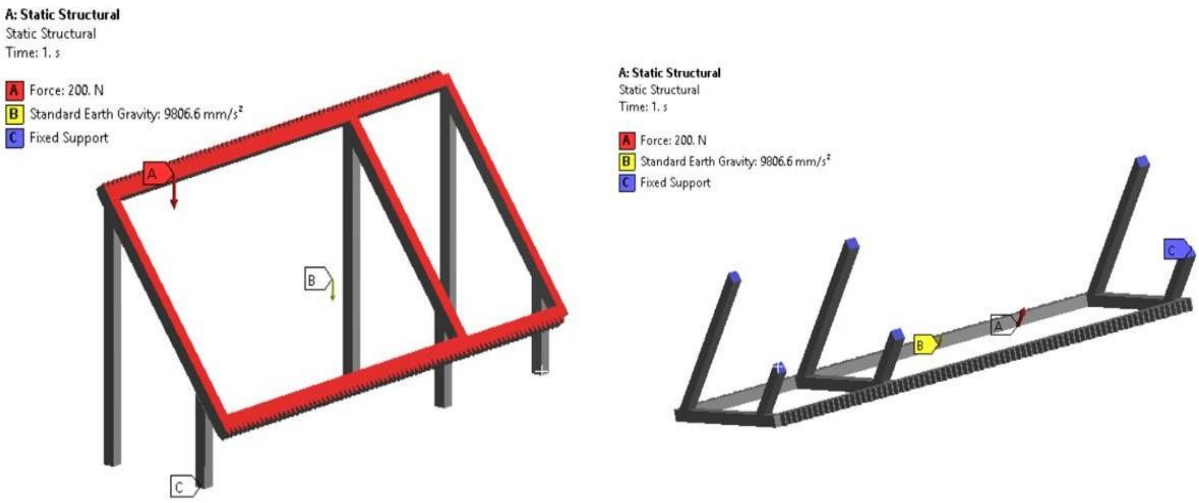
$d_p = m\ Z_p = 17m$ Q
= 2 Z_g / Z_g+ Z_p
= (2*17) / 34
= 1
$K = 0.16\ [BHN / 100]^2$
= O.16 $[197 / 100]^2$
= 0.620
F_w = $d_p * b * Q * k$
= (17m*10m*0.620)
= 105.4 m^2
$F_b > F_w$
Pair is weaker in pitting failure.

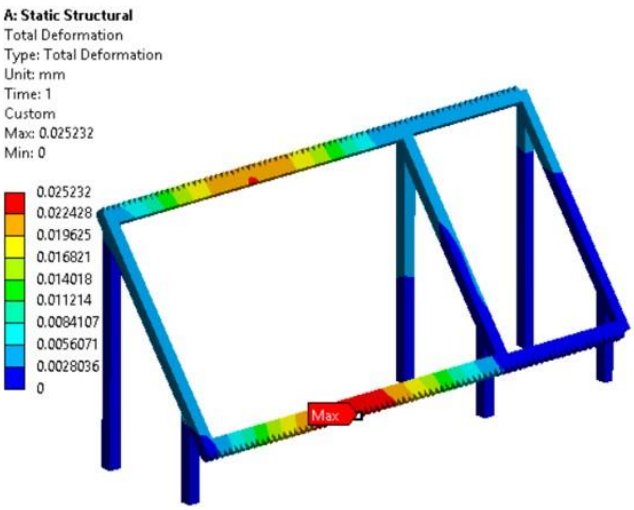
MOTOR SELECTION:
Consider weight of the consumable = 10kg (approximately)
So the force applied is equal to = 10x9.81 newton.
F= 98.1 N
Hence, the torque required = 98.1x 850 mm
= 83.385 N-m
So we have to select a motor having considerably similar torque as calculated

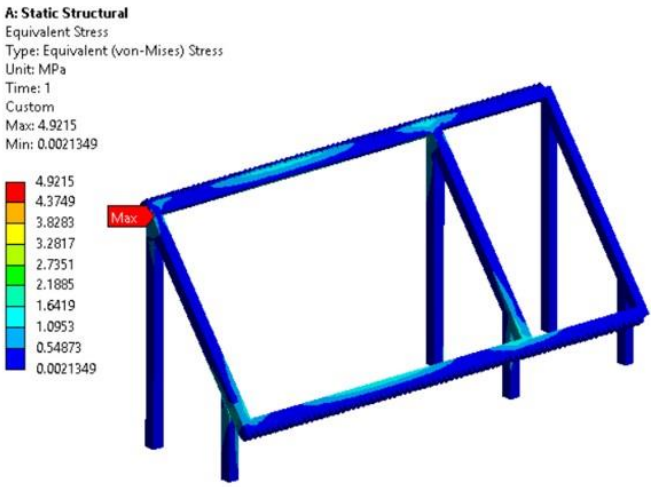
Experimental analysis



In solar panel cleaning machine convert cleaning mechanism to the force.
As we assume weight of cleaning mechanism is 15 Kg as we use M.S material. And applied weight of solar panel on structure.
So total weight applied on body is 20kg20 X 9.81 =
200 N
Boundary condition 2 - Standard earth gravity = 9.81 m/s2
boundary condition 3 (c) = Fixed supp ort at bottom face which rest on floor.







- we performed static analysis on solar panel cleaning frame by using ANSYS software.
- In ANSYS we use static structural tool to find out total deformation and equivalent stress obtained on frame.
- Maximum deformation and equivalent stress generated on frame is 0.05 mm and 4.9 MPa.
- The equivalent stress generated on frame is less than material yield strength so our design is safe.

IV. Conclusion and Future Scope

Conclusions:

1. This system of cleaning using robot can be applicable to any plant, it also guarantees a zero pressure on the Photo voltaic cells and is easy to control and maintain. Unfortunately, the only drawback is that it need to be installed manually to the next array. This problem can also be sorted if the solar plants are well designed. Rainy region could also create a problem for this design , as rain creates mud, and mud is hard to clean by using brushes only, so we would have to switch to cleaning using water and brushes that is the wet cleaning.
2. In this project we also performed static analysis on solar panel cleaning frame by using ANSYS software.
3. In ANSYS we used static structural tool to find out total deformation and equivalent stress obtained on frame.
4. Maximum deformation and equivalent stress generated on frame is 0.05 mm and 4.9 MPa.
5. The equivalent stress generated on frame is less than material yield strength so our design is safe.

Future Scope:

1. Furthermore, The next step or the future work would be to find a mechanism that allows the robot to move through spaces between arrays easily without any human intervention.
2. The solar panels can also be fitted with a mechanism in which they can track the sunlight and change their position accordinglyso as to attain maximum output of power generation even during cloudy days.
3. There is also one more future aspect i.e. The Nano man Solar Panel Coat, It is a nanotechnology enabled coating specially engineered for use on solar panels. Once applied it fundamentally changes the surface giving the surfaces hydrophobic and self-cleaning properties The coating's self-cleaning effect stops dust, pollen, pollution and bird dropings from sticking to PV panels, keeping them clean, maintaining their efficiency, ensuring the maximum amount of electricity is produced.

Acknowledgment

It is indeed a great pleasure and moment of immense satisfaction for me to present a seminar report on"**Automatic Solar Panel Cleaning Mechanism**" amongst a wide panorama that provided us inspiring guidance and encouragement, I take the opportunity to thanks to thanks those who gave us their indebted assistance. I wish to extend my cordial gratitude with profound thanks to our internal guide **Prof. S.A. Gurav**. It was his inspiration and encouragement which helped us in completing my work. My sincere thanks and deep gratitude to Head of Department, **Prof. D. H. Burande** and other faculty member; but also to all those individuals involved both directly and indirectly for their help in allaspect of the project..At last but not least I express my sincere thanks to the Institute's Principal **Dr. S. P. Patil**, for providing us infrastructure and technical environment.

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