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Design and Analysis of Auto Photovoltaic Solar Panel Cleaning System

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ABSTRACT: This research paper is about to design and analyse the auto photovoltaic solar panel cleaning system. Solar energy is the most abundant source of energy for all forms of life on the planet earth. Photovoltaic solar panels are one of the applications of solar energy. Growing interest in renewable energy has led the photovoltaic solar system to expand notably in the last decade. But efficiency of PV panel is reduced significantly due to various factors like bird dropping, dust, etc. To overcome this problem this project aims to design and analyse the solar panel cleaning system which will improve the efficiency of the panel and reduce the manpower.

KEYWORDS: Main frame, middle frame ,top frame, solar panel.

I. INTRODUCTION

In this paper Energy is one of the major issues that the all countries in the world are facing this problem. India is a developing country it also facing a problem of energy supply [1]. The energy supply is one of the major problems for both urban and rural households. Near about 60% to 70% of the energy demand of the country is met by non-renewable sources like petrol and diesel [1]. Solar energy is a renewable source of energy which is freely available in nature, which has a great potential and it is radiated by the sun. Renewable energy is important to replace the generation of electrical energy that can be done by petroleum. Solar power is a source of renewable energy and solar energy application should be enhanced.

Photovoltaic solar panels are one of the applications of solar energy. Solar panels are those devices which are used to absorb the sun's rays and convert them into electricity or heat [2]. Growing interest in renewable energy has led the solar photovoltaic (PV) system to expand notably in the last decade. In the year 2014 a staggering a 3.03-milliongigawatt hours (GWh) of electricity was produced in the European Union covering 3 percent of the total electricity demand [4]. Because Photovoltaic energy is an accessible technology, it has become a popular investment for companies as well as for residential users. Consequently, this demand has stimulated the research for increasing the overall output power of PV systems causing laboratories all over the globe to work hard on making the technology both more efficient and cost effective [3].

Achieving maximum efficiency has been a challenge, because according many case-studies it has been seen that the conversion efficiency ranges from 10 to 13% in commercial level. However, the outdoor installed PV modules efficiency may reduce by 10 to 25%. This efficiency changes are due to several factors like lower irradiance; higher air mass; regardless of this, solar radiation is failed to be harnessed due to accumulation of foreign particles like dust, bird dropping, snow and many other. Regardless of the effort of the industry or commercial area to shorten the payback time, a preventable loss namely soiling is often overlooked. As a result, a layer of dirt piles up on top of the glass reducing its transmittance and therefore decreasing the power output of the entire system. Besides the material and design parameters, there are several omnipresent factors such as dust, humidity and air velocity that can influence the PV cell's performance.

By increased wind velocity more heat can be removed from the PV cell surface. In the same vein, higher air velocity lowers the relative humidity of the atmospheric air in the surroundings which in turn leads to better efficiency. Electricity generated using solar photovoltaic (SPV) technology can only be economical if the PV

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modules operate reliably for 25– 30 years under field conditions [3].

Seeing that precipitation plays a considerable role in the cleaning capability it must be said that rainfall often does not suffice because of some types of soil, cement and stick. The same counts for bird droppings which don't flush away either. However, cleaning solar panels is not always as straightforward. To begin with, there is the issue of accessibility. Due to the fact that PV panels often are situated on dangerous and difficult to reach places, it might be hard to clean them manually and it takes the time to do it safely. However, leaving panels uncleaned might not be wise either since soiling can lead to permanent damage of the glass limiting the lifespan of the installation. The logical solution is to clean them automatically and autonomously [3].

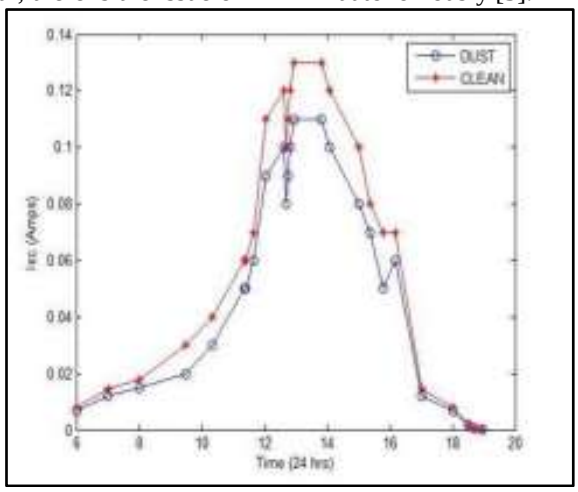

Fig1: Graph of ISC V/s Time for cleaned and dusty panel.

Making consideration of this facts and figures interlinked with efficiency reduction significant improvement in the output of the PV solar panels can be achieved by an effective method of cleaning. There have been number of cleaning technologies [5] but very few of them are condition based solar cleaners. When there is raining there might not be needed water. To sense the necessity of water and operate accordingly without human intervention an automatic PV cleaning system is needed.

So, we designed the cleaning system operated automatically which can be controlled by microcontroller according to the condition. It will save human time and manual work and save water.

1.2 PROBLEM STATEMENT

A lot happens inside the PV solar cells. The solar panels efficiency depends on a lot of factors such as; the ability of the panel to capture incoming sunlight, the ability of the panel to convey electrons that have the right energy amounts, and capacity to move the electrons freely around the circuit and to do work. The cells in a PV solar panel status such as lack of coating can impact the efficiency of the solar panels in production of energy. There are main four factors affecting the solar panel efficiency which are dust, humidity, temperature and natural degradation

1.2.1 DUST

Dust is solid particles that vary in sizes, which are suspended temporarily in gas but settle down due to gravity. The effect of accumulated dust is that it reduces the solar radiation incident. The transmission of radiation through dust collected panels is from 2% to 40% which is determined by the amount and size of dust particles, season and also the location. Research on the effect of dust on the solar panels in the desert areas found that there was 7% degradation in efficiency of the photovoltaic panels while the thermal panels only degraded by 2.8% to 7% (Maghami et.al, 2016). The accumulation of dust on the surfaces of the PV systems reduces the amount of radiation getting into the solar cells and thus translated to losses in the generation of power. Dry areas especially are affected by dust and. Hence, the performance of the solar PV systems could be reduced by up to 15% (Maghami et.al, 2016). Therefore cleaning with water is the only solution, but for large scale PV use the task is usually expensive.

1.2.2 HUMIDITY

100% of the energy coming from the sun, 30% of the energy is either reflected back to the clouds, oceans, and land masses (Khatib et.al,

2012). In places where the humidity is high ranging from 40- 78%, there is a minimal layer of water vapour at the front of the solar cell directly facing the sun. Therefore, the solar energy that strikes the solar panel is lost through reflection. The humidity creates hurdles for the energy received at the top of the atmosphere and also affects the devices consumption. Due to humidity, refraction appears which results in decreasing the intensity of light that in turn decreases the efficiency.

1.2.3 TEMPERATURE

Photovoltaic or the solar panels are used in the production of electricity. However, they are affected by their operating temperatures which are the product of the level of sunlight and then ambient air temperature. Temperature combined with other factors can reduce the efficiency and lower the PVs energy output. Notably, the production efficiency of the solar panel reduces in cases of hot temperatures. Ironically, the PV solar panels work most efficiently in low and cold temperatures (Han et.al, 2015). Cold and sunny environments offer optimal operating conditions for the solar panels. But, unfortunately in the coldest areas of the world have fragile sunshine making it impossible for the solar panels to receive adequate heat. The brightness of the sun in this areas also diminishes when the suns angle is low.

1.3 LITERATURE REVIEW

In this literature review we are studying the various types and methods of solar panel cleaning system which has experimented by others.

1.3.1Mukadam et.al

They designed and built an automated self-cleaning solar panel. The panel detects the occurrence of an impediment shading a cell, and actuates a cleaning mechanism that cleans off the impediment and consequently, restores the panel to normal capacity. To power the cleaning mechanism, they built our own power supplies which are supplied by a 12V battery. The fully assembled system was able to detect a shaded cell from debris. Furthermore, it initiated the wiper motion down and up the panel to clear the debris. Also, the system maintained the battery charged when there was no cleaning and sufficient power was available. More importantly, the project decreased the daily energy lost compared to the case where the PV panel was left shaded for an entire day.

1.3.2 Zelun Li et.al

The self-cleaning technology for solar cell array can promote efficiency of electricity produced and protect the solar cell. The dust removal method, such as natural way, mechanical way, self-cleaning Nano film, and electrostatic way are presented in this paper. Even though some methods for self-cleaning have been mentioned by many researchers, If the surfaces of the solar cell array were covered with a pellucid self-cleaning Nano film, it will keep clean. The self-cleaning Nano film is made of super hydrophobicity material or super-hydrophobic material. That is means the self-cleaning mechanism of the Nano film involve two strategies. The popular super hydrophilic film is TiO2, which has hydrophobicity and photo catalytic activity. The self-cleaning method consists of two stages. The first one is photo catalytic process which TiO2 film reacts under the ultraviolet light, and split the organics dirt.

1.3.3Sabah et.al

Sabah et.al in the previously done experiments, dust accumulation for the solar panels has been researched for a long period of time which is approximately about a year. The experiments have been prepared in different countries which is having climate conditions of the dusty weather. Those countries are Iraq, Egypt and UAE. The solar panels were not at all cleaned, at first for one month, then next for two months and so on. The results were like there was a decreasing effect in the transmittance of the solar panels, which is emphasizing the effect of accumulated dust, although the changing in the tilt angel which is in conjunction with the dust deposition on the panels. Actually, there are many benefits from such a project. First, economical benefit, where there is no more money will be paid to a cleaning agency. Next, it is time reduction, where there is no time will be spent to clean those solar panels.

1.3.4 Biswas et.al

Biswas et.al this paper presents a design of solar tracking system driven by 12V or 24V DC motor controlled by a microchip „Intelligent Drive unit IBL2403". The projected double axis rotation solar tracker ensures the optimization of solar energy conversion to electrical energy by the orientation of „titanium-oxide" PV panels in synchronization to the hemispherical position of the Sun. The hemispheroidal three dimensional rotational axle moves the PV panel along the Sun path. Efficient cooling system and dust control mechanism has been designed for maximum efficiency. Normally silicon based PV cells having 13% of conversion rate of solar to electrical energy, but the Titanium-oxide PV (ToPV) panels having 32% of conversion rate.

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1.3.5 Kawamoto et.al

Kawamoto et.al an improved cleaning system has been developed that uses electrostatic force to remove sand from the surface of solar panels. A single-phase high voltage is applied to parallel wire electrodes embedded in the cover glass plate of a solar panel. It has been verified that more than 90% of the adhering sand is repelled from the surface of to some extent inclined panel after the cleaning action. The performance of the system was further improved by improving the electrode configuration and introducing natural wind on the surface of the panel, even when the deposition of sand on the panel is extremely high. The power consumption of this system is virtually zero. An improved cleaning system for removal of the sand that accumulates on solar panels using electrostatic force has been developed. This system is suitable for use in mega solar power plants constructed in deserts at low latitudes because it is potentially inexpensive, requires virtually no power, and operates automatically without water and other consumables.

1.3.6 Bansal et.al

Bansal et.al the energy or efficiency produced by solar photovoltaic modules is related with the Sun's available irradiance and spectral content, as well as other factors like environmental, climatic, component performance and inherent system. These dust, dirt and bird droppings are the major reasons for the solar photovoltaic system underperformance. This paper discusses a comprehensive overview of dust problem and the recent developments made on automated cleaning system for solar photovoltaic modules which give brief overview on techniques like electrical, mechanical, chemical and electrostatic.

1.3.7 Kulkarni.al

Kulkarni.al the solar PV modules are generally employed in dirty environment which is the case in tropical countries like India. The dust accumulation on the surface of a photovoltaic (PV) module decreases the radiation getting the solar cell and produces losses in the generation of voltage and power. Dust not only decreases the radiations on the solar cell, but also changes the dependence on the incidence angle of such radiation. According to the research, the daily energy loss along a year caused by dust deposited on the surface of the PV module is around 4.4%. In long periods with no rain, every day energy losses can be more than 20 %.

1.4 DESIGN OF SOLAR PANELCLEANING SYSTEM

The prototype of cleaning system is developed in Solidworks. This model is developed according to the dimensions of the solar panel where it can be easily mounted. The design part includes the analytical as well as the analysis part. The frame is designed considering the bending stresses developed in the members.

Material	Aluminium(Al)
Yield Strength	50 N/mm^2
Elastic Modulus	6900 N/mm^2
Poisson's Ratio	0.33
Mass Density	2.7 g/cm^3

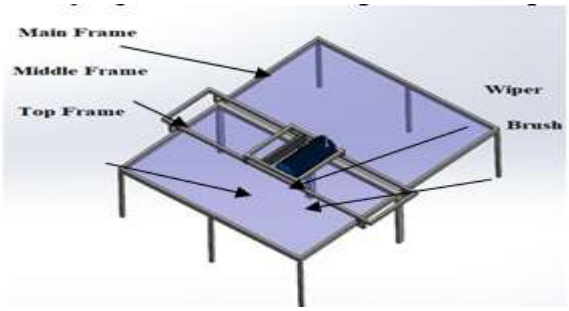

Fig 2 Modelling of auto photovoltaic solar panel cleaning system

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Parts:

Part No.	Part Name
1	Main Frame
2	Middle Frame
3	Top Frame
4	Wiper
5	Brush

As the fig 2 shows the design of main frame[1]and the cleaning system mechanism, which consist of the main frame on which the solar panel is mounted. And the middle frame [2] which moves horizontally along with the top frame [3]. Top frame [3] is mounted on the middle frame [2] which has the wiper[4] and the roller brush[5] for cleaning the solar panel, and this top frame moves vertically as the middle frame[2] moves horizontally. This way the cleaning system works to clean the solar panel.

1.5 ANALYSIS OF SOLAR PANEL CLEANING SYSTEM

1.5.1 DISPLACEMENT IN MAIN FRAME

The solar panel is mounted on the main frame. So due to the continuous load and the stresses acted on the main frame the frame can be deformed. So this deformation is showed in fig 3 below.

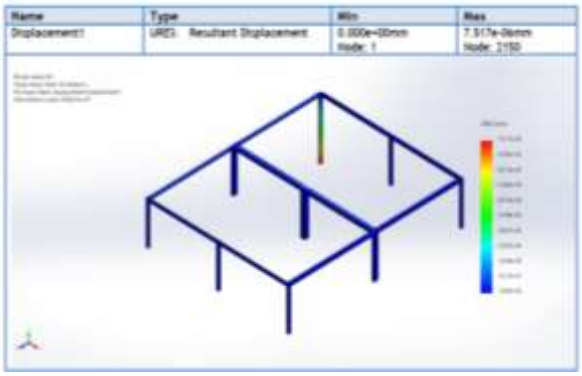

Fig 3 Displacement in the main frame

Density of material = 2.7g/cm^3
Young's modulus (E) = 69 GPa
Weight = 501.12 N
Area = [(1701.80*2082.80) – (1651*2032)] + (50.8*1651)
= 286044.64 mm^2

$I = \frac{BD^3 - bd^3}{12} = \frac{1701.80*2082.80^3}{12}$
$=211.437 * 10^9$ mm^4

$y_{max} = \frac{wL^3}{48EI} = \frac{501.12* 2082.80*10\text{^}6}{48*6.9*10^{10}*211.437*10^9}$
$= 6.46*10^{-6}$ mm

1.5.2 DISPLACEMENT IN MIDDLE FRAME

The middle frame is placed on the main frame with rollers which helps the frame to move horizontally. And on the top of the middle frame the top frame is placed. The stresses results to deformation of Middle frame. This shows below fig 4.

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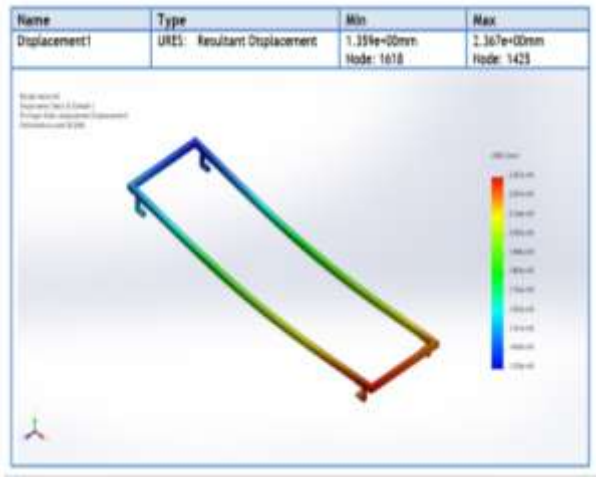

Fig 4 Displacement in the middle frame

Density of material = 2.7g/cm^3
Young's modulus (E) = 69 GPa
Weight = 68.63 N
Area = (495.3*1955.8) – (444.5*1905) = 121935.24 mm^2
$I = \frac{BD^3 - bd^3}{12} = \frac{(495.3*1955.80^3) - (444.50*1905^3)}{12}$
$=75.23*10^3$ mm^4
$M = \frac{wL}{4} = \frac{68.63*1955.80}{4} = 40099.57$ Nmm

$y_{max} = \frac{wL^3}{48EI} = \frac{68.63*1955.80*10^6}{48*6.9*10^{10}*75.23*10^3}$
= 2.06 mm

1.5.3 DISPLACEMENT IN TOP FRAME

The top frame is mounted on the middle frame of the cleaning system. Top frame has wiper and roller brush attached to it.
The deformation is shown below.

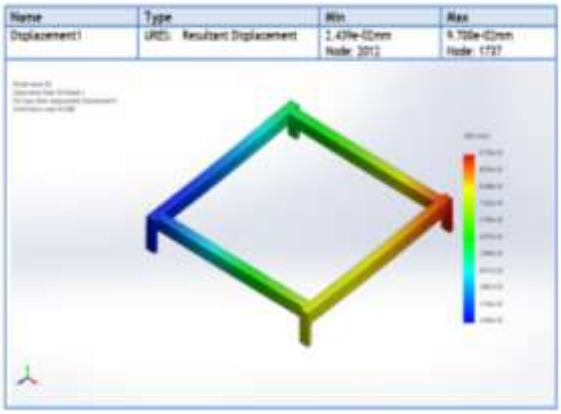

Fig 5. Displacement in the middle frame

Density of material = 2.7g/cm^3
Young's modulus (E) = 69 GPa
Weight = 31.88 N
Area = 237.096 cm^2

$I = \frac{bd^3}{12} = \frac{495.3*244.475^3}{12} = 133422096$mm^2

$M = \frac{wL}{4} = \frac{31.88*495.3}{4} = 3947.541$ Nmm

$y_{max} = \frac{wL^3}{48EI} = \frac{31.88*495.3^3*10^6}{48*6.9*10^{10}*133422096}$
=0.092 mm

CONCLUSION AND FUTURE SCOPE

1 The detail study of existing model solar panel cleaning system has been done. It is found that most of them are not condition based solar cleaners.

2 Designed optimized cleaning system by performing various mathematical calculations.
3 The stress analysis for all frames has been carried out and found that these stresses are within permissible limit.
4 The future scope of this is to manufacture the proposed design and performance evolution can be carried out by developing experimental setup.

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