Solar Panel Cleaning Bot For Enhancement of Efficiency- An Innovative Approach

Prof. J. B. Jawale, Prof. V. K. Karra, Dr. B. P. Patil, Puneet Singh, Shailender Singh,Saloni Atre
Department of Electronics and Telecommunication Engineering
Army Institute of Technology,Dighi Hills
Pune,India
Email:jjawale@aitpune.edu.in , vkarra@aitpune.edu.in , principal@aitpune.edu.in ,puneetsingh93@live.com, shailendrasinghkushwaha_12618@aitpune.edu.in , saloniatre@gmail.com

***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 solar panels. Accumulation of dust and debris on even one panel in an array reduces their efficiency in energy generation considerably and emphasizes the need to keep the panels' surface as clean as possible. Current labor-based cleaning methods for solar 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 solar panels, which can clean and maneuver on the glass surface of a Solar panel array at varying angles from horizontal to vertical.**

This is done with the help of Microcontroller board Arduino Uno R3 which easily controls all the devices used in this particular model and therefore helps us to understand the required parameters which deal with the change in efficiency brought about by the cleansing of the solar panel arrays.

Keywords-Arduino Uno R3, cleaning, eco-friendly, Solar panel, time/cost effective

I. INTRODUCTION

Installations of solarpanel array are becoming more ubiquitous all over the globe. Each and every solar panel parkhas a life expectancy of 21 – 26 years, and it is extremely important to optimize and utilize the power generation potential on a regular as well as daily basis. The accumulation of disambiguated particles, refuse, wreckage and waste on the surface of photovoltaic panels affects the performance of the solar panel in the same way as if on a cloudy day which in turn means that it is not at all utilised in a proper manner. This is especially knotty and troublesome indry, xeric and dusty environments which constitutes of majority of regions around the nation. There is an immediate necessity of an automated cleaning solution to this intricate issue which can provide services to a large ground based solar arrays up to an operating park of 1800 panels (1050square meters).

A systematic and effective robotic device[7] can help such large scale parks in cleaningas well as in auto inspection of panels alongsidepower consumption and low water utilisation when compared to intervention of manual cleaning and present mechanical substitutes. A solar cell is an electronic device that provides electricity by conversion of solar energy provided by sun into electrical energy by flow of electrons between two layers of semiconductors. In order for the photovoltaic cells to operate at optimum efficiency without any loss of energy (zero energy loss), the surface of panel need to be dust free and in absence of any kind particle which obstructs the flow of photons[1][2]. Dirt, Dust, wastage as well as clouds bring about obstruction in the working of solar cells and have same effect collectively. Cloudy conditions block absorption and can reduce the efficiency of the panels by 22% - 76%.For maximum output we need to keep the panels and in thus arrays clean with the help of highly controlled process. We need to use water for the cleansing process because it helps in improving the efficiency as it is known that most of the commercial crystalline silicon photovoltaic cells observe a suitable current-voltage characteristic at lower temperatures.. This relates to the use of water by the bot to be sprayed on the photovoltaic cells which improves its efficiency by more than 15%.Automation is essentially required with this process since it has a better perspective in both utilisation as well as brings about better handling by human and reduces manual inspection, hence there is a abreast of cleaning system with auto lining features.Extremely important advantage of an automated robotized answer for the question raised about the cleaning of solar panels is the robustness, thoroughness, test-retest reliability and optimized speed of cleaning with which the controlled process works in comparison to traditional methods. This paper presents a cost effective bot for an extremely optimized cleaning of solar panel arrays. As we can observe from the Fig.1 that cloudy days have major affect on the output of solar energy. The first few curves in the graph depict extremely low output as compared to later curves.

978-1-5090-2309-7/16/$31.00©2016 IEEE

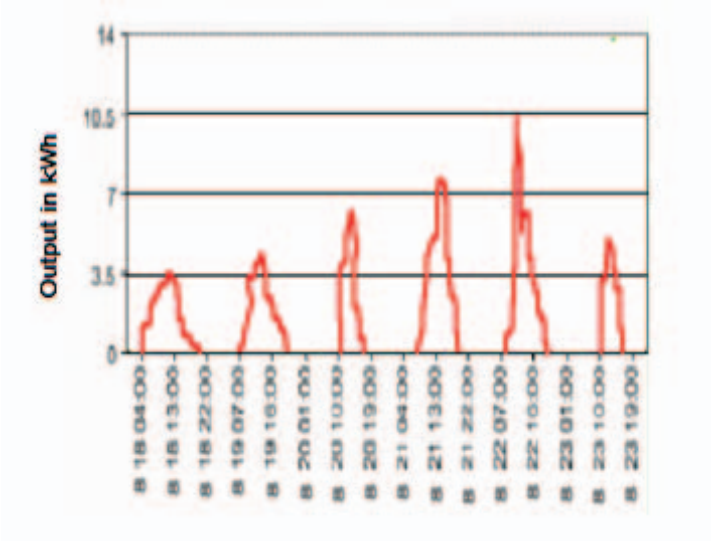

Figure 1: Response of 8-panel situated on the top of AIT Pune during cloudy days which is equivalent to output due to settlement of dust and dirt particles.

A vast number of input parameters such as amount of water to be sprayed, direction of water, number of times brush to be rubbed, type of rotor material and many more are varied to conduct scrubbing and observe the variation in mainly three output parameters which are how good a panel is cleaned, time interval required to clean a single panel and amount of water used during the process being proclaimed.Ordinarily, the owners of solar panel find it quite difficult to wash and scrub the solar panels alone or by hiring labour over a period of a few days, whereby it is extremely tough and even nearly impossible for some individuals who stay at place away from their solar farm or arrays of solar panels. An object of this invention, therefore, is to provide a systematic device for cleaning of solar panels that is simple in construction, efficient in operation, and which will automatically scrub smut and clear dust off the panels at spaced intervals throughout a week, for several days at a time.

II.LITERATURE SURVEY

Solar industry has shown an accelerated growth over the last few decades, however solar panel cleaning and contingency planning has attracted very least amount of centre of attention.Arrays with less number of panels are cleaned with the help of a mop and soap water solution which has less speed of less than $2m^2$ / minute[4].Solar parks i.e. solar panels with large number of arrays are washed with the help of fire hose pipe which not only wastes a large amount of water but also reduces any kind of specific cleansing. A solar farm (Charanka solar park) in Gujarat, India spread across 2000 hectare site for example uses over 220litres of water to clean a 10 square meter array. Present technologies include hand cleaning device for maintenance of solar panels is the tucker pole which has brittle hand nylon brush attached with pole and in some cases provided with water spray system and allows two people to clean a array of 48 solar cells of 4 x 4 size in less than 3 hours.

The problem occurs when the smut inclusive of bird droppings has settled on the surface of the panel and is at a particular height which is difficult for mop to rub it off and there's no one over there to have a better clarity of cleaning. And hired labour is not aware of the amount of water they should direct without harming the solar panel as well as without wastage. Therefore to solve the problem, system that can automatically control the water without the involvement of the owner user is needed to make sure that there is minimal water wastage.

Currently small residential and office space use small size solar panel which does not hinder the instalment and hence to clean those small panel arrays SolarWash[4][7] is residing in market which is an automated cleaning system consisting of series of nozzles which are equally spaced from each other and release the flow of water when it is controlled by microcontroller or processor. The disadvantage associated with this design is increase in loss of water due to non-specific cleaning of solar panel as well as low speed which doesn't allow this model to be used in large solar farms. The water flow is unable to cross the horizontal gaps between panel edges

For the past ten years the industries main focus has been on reducing the physical barriers by the inventing an automated system which will timely and efficiently clean the solar panel with minimal manual intervention as well as light weighted and sophisticated. The testing environments have made it possible to improve the capacity factor from 35% to 45%. A major portion of this improvement goes to increasing the size of the mop, improvement in the rotor mechanics and also the material of the mop which affects the dynamics associated with the operation of these cleaning systems.

NASA has researched the decreased efficiency due to dust and buildup in relation to number of days on Mars[6]. For a 30 day mission they suffered more than 52.2% power loss, and accounted for 89% power loss over the next two years. However, due to some fateMars rover went through an unexpected wind (Martian Wind) which cleared all the dust settled on the panels partially helping NASA to in their accelerating their electrical output. Glass cleaning methods are also quite prevalent since cleaning of a glass panel is somewhat equivalent to cleaning of solar panel array. A large number of such glass panes cleaning robots exist, the most famous being the Robuglass robot designed to clean the Louvre glass pyramid in Paris, France. Excessive cleaning of glass panels can sometimes lead to micro scratches which have no adverse affect

on the functionality of a window, but scatter light entering a solar panel. Currently no robotic system exists to perform the cleaning of the glass surfaces of solar panels.

III.METHODOLOGY

The Bot for cleaning of panel designed in this case is composed of a cleaning head that moves across the panels with the help if stainless steel rod using a pair of motorized trolleys. This design was selected because of its less cost involvement, simplicity, and robustness. The risk of scratching the glass surface leads us to the movement with the help of wheels and manual force. The test-retest ability of this design allows acceptable continuous functionality on a wide range of array dimensions. Although not all panels or arrays are of the same size, but the system is adaptable due to its ideal size and adjustment of stainless rod.. The panel columns have continuous travel since the robot can cross the side edges between the panel frames.

Steps involved in the implementation of model of Cost Effective Bot for Cleaning Solar Panel Array are as follows:-
a) Supportive Frame: In the present embodiment of this invention there is a presence of frame which is made using aluminium alloy of 3xxx series (3003) consisting of manganese. These alloys are moderate in strength, have a good formability and are suitable for welding and anodizing. This frame is of 3 mm thickness with tolerance 0.720 to 1.40mm+/-0.080mm and density 2.73 g/cm3. The length of the frame is 730mm whereas breadth is 100mm.

b) Shaft: The shaft used in the embodiment is made up of Mild Steel consisting of approximately 0.05–0.15% carbon having density 7.85g/cm3 and young's modulus of 210 GPa (30,000,000 psi). The shaft is of length 520 mm with diameter of 12mm.

c) Motor: DC geared motor with 360o rotation is used which is easily available in market and is used with shaft to shaft mounting. The motor is having a torque 13kgcm with speed of 500 RPM. The shaft length is of 18mm with a diameter of 8mm. It has a weight of 350 grams.

d) Brush: Industrial roller brushes made up of nylon fibres having outer diameter of 75mm and inner diameter of 11.8 mm. are used for scrubbing purpose

e) Motor Mounting: Motor mounting is made using aluminium alloy of 1200 H16 temper having strength of approximately 150 MPa. The length of this mounting is 100 mm and width 50 mm with thickness 7mm.

f) Ball Bearing: Ball bearing of inner diameter 12 mm whereas outer diameter 28 mm is used to provide a smooth movement to shaft. The bearing is made up of Mild steel of same specifications used is shaft. The width of Bearing is 8mm.

g) Bearing Housing: Bearing housing is made up Mild Steel of same specification as of shaft. It has inner diameter of 28.1mm and outer diameter of 40mm.It has width of 12 mm.

h) Bearing Mounting: Bearing mounting is made using aluminium alloy of 1200 H18 temper having strength of approximately 140 MPa. The length of this mounting is 80 mm and width 40 mm with thickness 6mm.

i) Wheels: Four wheels of diameter 24mm, made up of polyolefin are attached on both the sides of frame so as to give better movement to the embodiment.

j) Handle: U-shaped structure made up of 3xxx series (3003) consisting of manganese is attached to the supporting frame so as to give movement to the invention. Its total length is 620mm.

k) Nozzle: Copper nozzle which gives a flat fan spray pattern since it has a V-notch at the condescending inlet joined to PVC pipe using Barbs.

l) Arduino Uno: Microcontroller ATmega328P having operating voltage 5V used to control the circuit like DC motor driver, 16X2 LCD and solenoid valve.

m) 16X2 LCD: To display the speed of dc motor which is directly controlled by Arduino Uno R3 is also attached

n) Solenoid Valve: 2-port solenoid valve having input voltage of 12V to control the wastage of water.

o) LiPo Battery: LiPo cells provide manufacturers with compelling advantages. These batteries are long durable and provide constant output of 12V continuously.

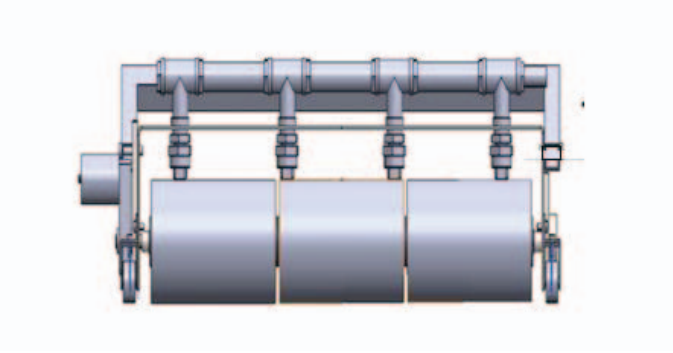

Figure 2: Front View of the robotic device for solar panel cleaning

Solar panel cleaning Bot is a cleansing device mainly focussed on cleaning solar panel at high speed with minimal amount of manual intervention and low level of water usage. Referring to Fig. 2 which is the front view of the embodiment, the basic feature which helps in cleaning of dirt from the surface of the

panel are the nylon brushes. These nylon brushes are hollow cylinders of length 160mm with outer diameter of 75 mm and inner diameter of 11.8 mm weighing 120 gms. These brushes have nylon filaments in a group of 50 with a spacing of 20 mm between two consecutive groups in either direction. Three brushes are used and held together using shaft made up of Mild Steel with density of 7.85g/cm3 of 520 mm and 12mm diameter , two slots are made available at a equidistance of 20mm from both the ends to give provision to two things i.e. lacking clips to avoid movement of brushes in horizontal motion and a hole for grub screw to tighten the shaft of motor which will enter the tapered bore of 8mm in the shaft . The Brushes are tightly packed so as to give a good deburring application. The shaft is provided with support from the aluminium frame which is 3mm thickness and of dimension 730mm x 100 mm bent at right angle at 100 mm from both the ends. These bent portions consist of tapered hole of width 8mm terminating with semicircles of radii 3mm along with two holes of 3mm diameter. The tapered hole is present at a distance of 40 mm from the end of the frame. The brushes are rotated with the help of DC geared motor which gives a torque of 13 kg-cm with the help of gear box which has numerous gears to provide such high torque resulting on rotation of shaft and in turn the brushes as well. Motor needs battery of 12V to operate at its optimum capacity. The motor is held in place using mounting as shown in consisting of circular hole of diameter 25 mm for the motor shaft as well as two tapered holes which are of length 8mm terminating with semicircles of radii 3mm which are in alignment. The screw used to put these holes together is Full thread M3 socket head cap screw of 8 mm length. To adjust the shaft in the vertical direction we can easily loosen up the screw a bit and provide movement with the help of tapered holes present in the mounting. The opposite end of shaft terminates in radial ball bearing to provide better rotation. This ball bearing has outer diameter of 28 mm whereas inner diameter of 12 mm. This bearing is kept in covering known as bearing housing of inner diameter of 28.1 mm and outer diameter of 40 mm. This bearing housing is kept in place using bearing mounting shown in which has two tapered holes which serve same purpose as it did in the case of motor mounting. However there is a circular hole of 42mm diameter for the bearing to get easily attached to the mounting.

Along with rubbing the dirty surface we also need to wash it sometimes with high pressure water pointed at the surface in a particular pattern. This is achieved with the help of copper nozzle which is a flat fan spray pattern since it has a V-notch at the condescending inlet. The inlet with two directions for the water to flow through i.e. towards the next nozzle i.e. outlet and towards the V-Notch of 1mm through passage. The pressure of water is high due to top V-Notch which reduces the area that water tends to flow through and hence it follows a pattern of horizontal spraying. So as to cover the area cleaned by the brushes we require 4 nozzles connected with each other with the help of fibre reinforced PVC pipe. This pipe is easily available in the market; however you require barb made up of brass to connect these nozzles with each other. The fourth nozzle is terminated with a stopper so as to avoid further flow of water. On the other end the barb is connected to water connection of the building.

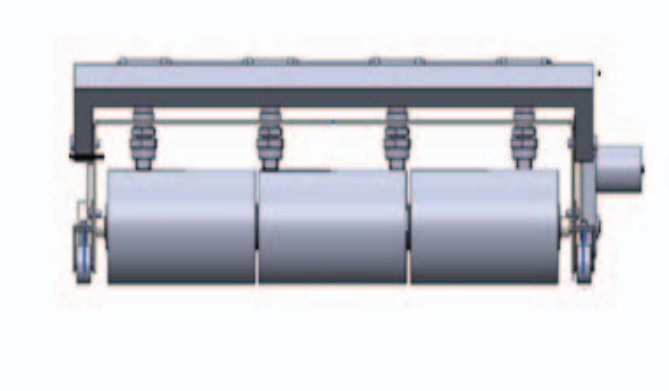

Figure 3: Back View of the robotic device for solar panel cleaning

Four wheels are attached on both the sides of frame so as to give better movement to the embodiment. Wheels are made up of polyolefin which is very durable plastic has outer diameter of 24 mm. Now to provide support without increasing the weight we have used 3mm V-shaped aluminium frame so as to provide light weightiness along with strong resistance to shocks. Now to place these wheels on the main frame we require mounting which is shaped in right angle and fixed with the V-shaped aluminium frame with the help of is Full thread M3 socket head cap screw of 8 mm length whereas it is attached to the main frame with the help of is Full thread M6 socket head cap screw of 12 mm length. All the wheels are attached to the respective corners of the main frame.

For the movement of whole embodiment with the help of wheels we have to push it using a uniform weight distributor which is a U-shaped Aluminium structure which is attached to the main frame using M8 countersunk screws of length 14 mm on both sides of the frame. This structure 14 is made by attaching three hollow cuboids of length 530 mm, 50 mm and 50 mm respectively. By applying minimal force to this structure we can move the whole embodiment.

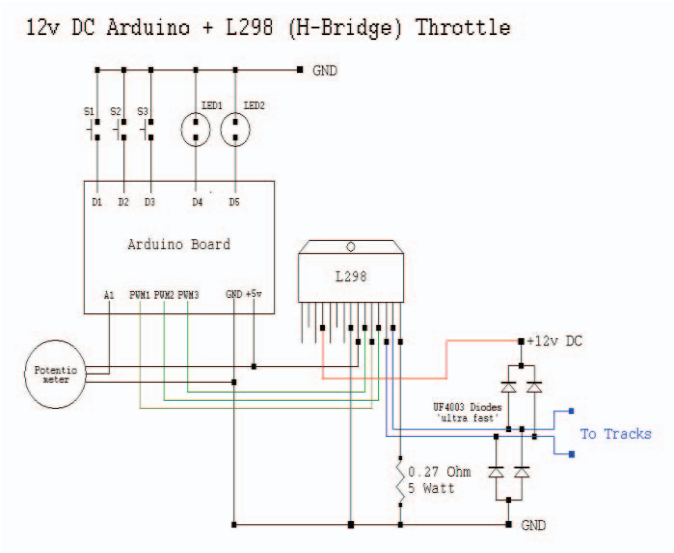

Figure4: Circuitry involved in driving of motors

The motor is driven by Arduino UNO R3 using motor driver L298N which in turn is controlled by Arduino. Power is provided to Arduino using a Li-Po 12V battery which is charged using power supply of 18 V and 1.5 A.Solenoid valve is controlled according to the timing of the Arduino and thus stops the flow of the water. LCD displays the speed of the motor and the direction of the motion accordingly. Coding is done in Arduinoitself.The foregoing objects of the invention are accomplished and the problems and shortcomings associated with prior art techniques and approaches are overcome by the present invention described in the present embodiment.

IV. PROTOTYPE AND INITIAL EXPERIMENT

The first prototype developed was experimented on 8-panel instalment which consists of polycrystalline silicon panels. It uses 9 YC500A Grid-Tie microinverters. The bot is placed on the panels and moved in vertical as well as horizontal directions and hence cleaning of 8-panel takes about roughly 4 minutes along with removal of smut and dust settled on the panel. The panel is cleaned twice a month i.e. on 5th and 20th day of the month. The output power is observed one day before cleaning and then after cleaning and the results obtained are remarkably great as shown in Table 1.

AVERAGE EFFICIENCY BEFORE CLEANING OF PANEL = 46.8 %(average output power obtained is 7.5 kWh)

AVERAGE EFFICIENCY AFTER CLEANING OF PANEL = 78.12 %(average output power obtained is 12.5 kWh)

RISE IN EFFICIENCY = 31.32%

TABLE 1: Observations of Power obtained when dirty and when cleaned.

S.No.	Date	Ideal Power (kWh)	Output Power Generated (Before Cleaning)	Output Power Generated (After Cleaning)
1.	5/4/2015	16	9.7	13.1
2.	20/4/2015	16	5.6	12.9
3.	5/5/2015	16	7.3	12.9
4.	20/5/2015	16	7.6	12.9
5.	5/6/2015	16	7.8	12.8
6.	20/6/2015	16	7.3	12.9

As we can observe in the Figures down below that after we clean the solar panel array on 5th day and 20th day there is a rise in output power i.e. from 7.3 kWh to 12.9 kWh on 5th day whereas on 20th day it's from 7.6 kWh to 12.9 kWh. Roughly after cleaning of the solar panel the optimized output is around 12.9 kWh.

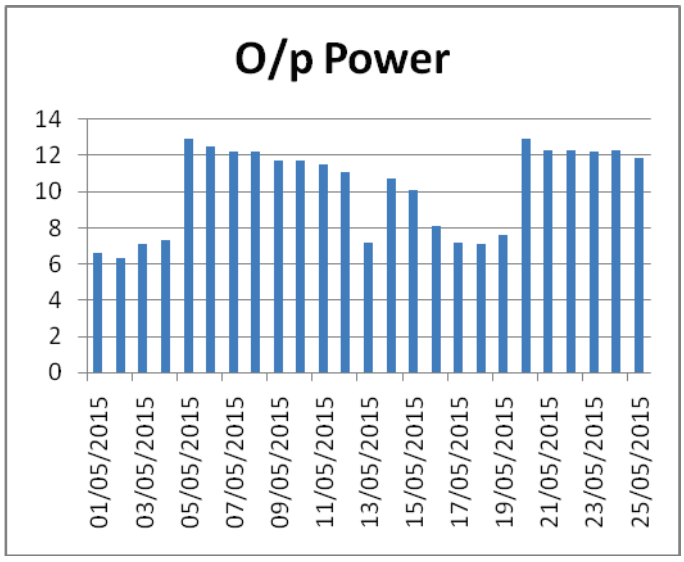

Figure5: Power levels in 25 days of May 2015

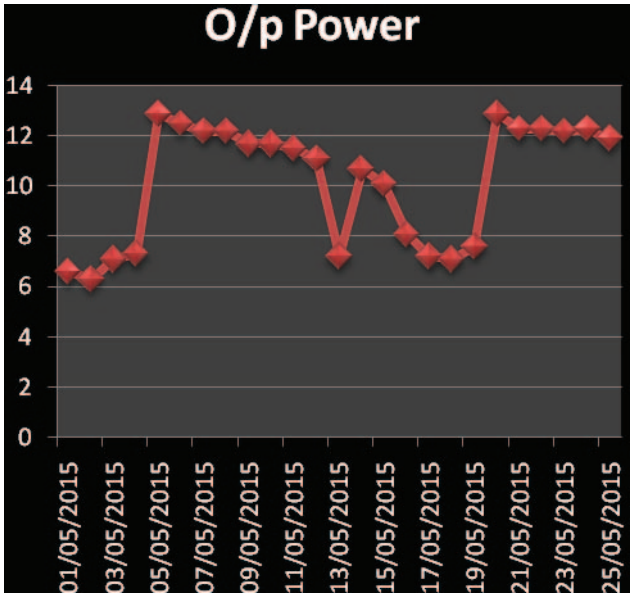

Figure6: Curve established using the results of cleaning showing hike in the output power level

There is a spike in the line graph on the 5th and 20th day and also depreciation on 14th day of the month which was due to cloudy conditions.

V. CONCLUSION

Cleaning and maintenance is extremely important aspect of solar panel efficiency. Increase in efficiency by 30%-33% is observed on 8-panel array hence in turn we can observe that it will be of greater use in solar park where number of cells is extremely larger. Complete cleaning is extremelyadvantageous since the hindering of a single panel with accumulated dust affects the efficiency for the entire array. It is extremely important that all cells operate at peak efficiency since they are connected in series..

Further development aims at optimizing the system to be smaller, lighter, easier to ensemble in higher volume and more eco-friendly. More focus will be lighted on auto-lining features, robustness, speed, and improving the intelligence of the bot overall.Installation of thermal camera module and proximity sensors will allow inspection of the solar panel more easily and improves the contact with every panel.Cleaning more arrays in one go would definitely be a challenge however design should be more universal so as to fit to almost every panel size all across the globe. Detection of cell damage and panel damage should also be recognised and the whole system should be completely controlled by single remote control.

Present embodiment has a pending patent under the application number 2662/DEL/2015.

VI. ACKNOWLEDGMENT

We would like to thank Army Institute of Technology, for providing us the opportunity and facilities in the department to develop and complete our project along with contribution made by Mr.AnupDevikar ,Keerti Enterprises for helping us in financial aid. We would also like to thank our families and friends for providing constant support and assistance even from distances.

REFERENCES

[1]MS El-Shobokshy, FM Hussein*, Sol Energy,59, 505 (2011)*.

[2] H. K. Elminir , A. E. Ghitas, R. H. Hamid, F. El-Hussainy, M.M. Beheary, K. M. Abdel-Moneim, *Energy Conversion and Management, 47, 3192 (2009).*

[3] O. Seely, "Some Observations on Photovoltaic Cell Panels," 6 Nov. 2008, http*://www.csudh.edu/oliver/smt310-handouts/solarpan/solarpan.htm*

[4] H. Hayden, P. Johnston, V. Garboushian, D. Roubideaux, "*APS Installation and Operation of 300 kW of Amonix High Concentration PV Systems", Proc. 29th IEEE Photovoltaic Specialists Conf., New Orleans, USA,* (2012).

[5]*OSC Energy Inc., SolarWash, 7 Nov. 2011, http://www.ocsenergy.com*.

[6] NASA Jet Propulsion Laboratory, "*Spirit Gets Energy Boost from Cleaner Solar Panels", Press Release February 12, 2009, http://www.jpl.nasa.gov/news/news.cfm?release=2009-020a*

[7] A. *Kochan, Industrial Robot,* 32, 380, (2005).