Design and Development of Automated Solar Panel Cleaning Device

Hrishikesh R. Paradkar [1] Mahavir R. Katariya [2] Dipesh D. Narayankar [3] Atharva H. Shastri [4] Prof. Sandip Shirsath[5]
Department of Mechanical Engineering, Keystone school of Engineering, Savitribai Phule Pune University.

Abstract:

The increasing awareness about the utilization renewable sources has helped solar energy to reach its pinnacle. The solar energy has grabbed the eyeball attention of much research organization to improve its efficiency. However the maintenance issue still remains ignored. This causes significant decrease in solar PV panels efficiency .The accumulated dust on solar panel block the cell from the sun's radiation and act as a adverse screening effect, it is necessary to keep the solar cells in pristine condition. The current solar panel cleaning methods like manual cleaning, water jet cleaning and robots used in large scale industries. But every cleaning method mentioned above have their own set of limitations to find its application in domestic sector. In this research the automated cleaning device is developed to fulfill the requirements of domestic sector. The main feature of this device is that it ensures three times cleaning of PV panels in its every pass. The device operates on electricity generated by the solar PV panels. The regular cleaning of PV panels using this device will increase the efficiency by 24 – 29 %. Thus the device positions itself as an economical alternative for domestic sector.

Keywords: Screening effect, Maintenance issue, Domestic Sector, Automated cleaning, 3X cleaning, Economical.

I. *Introduction:*

The Paris climate summit in 2016 passed a resolution to limit the rise in global temperature upto 1.5 degree centigrade by 2100. The main highlight of this summit was establishment of International Solar Alliance (ISA).It includes 121 countries from tropical region and this alliance aims to facilitate efficient exploitation of solar energy. Solar energy is seen as the most viable and economical alternative over non-renewable energy sources. The major advantage of solar energy is the reduction in annual greenhouse emission by several hundred tons. This has lead to increase in demand for solar PV modules and has encouraged the engineers to work on improving its efficiency and cost effectiveness.

Since 2000, there has been exponential growth in generation of solar energy which 14 GW to 405 GW in 2018, 89% of which was installed in last 7 years. There are several losses linked with power generation using solar cell panels like soiling , dusting , bird dropping , shading , sun tracking etc. From the above mentioned losses the most wariasm is soiling and dusting in tropical countries. So , in these areas there is only one option to maintain the PV modules to give its optimum output is Automated Solar Panel Cleaning Tool {ASPECT} which is the main focus area of this research paper . The dust accumulation on solar PV module depends on degree of tilt angle and geographical areas. The improper maintenance renders the entire solar panel setup futile. Specially, domestic sector invests large amount of capital for installation of solar panel setup. And if it is not properly maintained then entire setup will not able to produce adequate power output. The available cleaning methods are manual cleaning, water jet cleaning, robotic cleaning .From the above mentioned methods every method has its own drawbacks. In manual cleaning there is a risk of human life because of solar PV panels are mounted on roof tops to avoid shading losses. In water jet cleaning method there is colossal loss of water and robotic cleaning method are only developed to maintain large scale solar setup .The cleaning methods used in large solar energy producing plants are quite expensive to implement in domestic sector. Therefore, domestic sector does not have proper facility to maintain solar panel setup.

The U.S. Department of Energy mentioned the figures which state that Solar PV Panel efficiency reduces by about 6% to 8% only from airborne dust particles. In addition to that water streaking and bird dropping reduces efficiency as much as 14% to 31%. If small portion of the solar panel is left unclean then the power generation of the consecutive solar cells will get hampered.

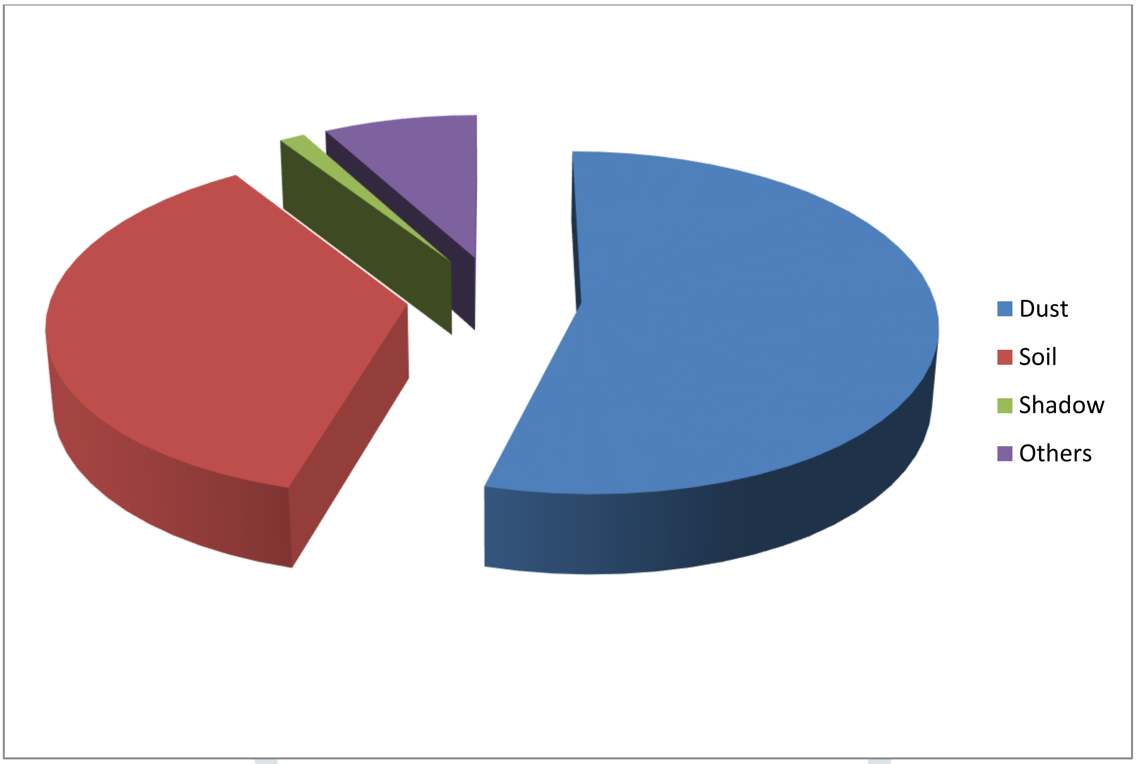


Figure 1: Factors affecting efficiency of solar panel

The domestic sector hires solar panel cleaning agencies which charge around $200-$220 for duration of half year even though their maintenance performance is not upto the mark. This tends to diminish the performance of solar panel setup and further worsen the scenario. By using the device mentioned in this research paper {ASPECT},this solar panel cleaning device cleans 3 times per pass as compared to other existing methods. The device will maintain the solar panel setup at its optimum output.

II Objectives:

- **Manufacturing of cost effective device:**
  The Automated solar panel cleaning tool {ASPECT} will be easily available and clean the solar panels irrespective of its size. This device will cost around $120.

- **Self-Powered:**
  The device is independent of external electric grid supply. It will consume electric power stored in batteries (12V 14AH) which gets charged by solar panels. Solar panel with specification of 20W will be mounted on the device.

- **3X cleaning:**
  In this device {ASPECT} consists of 3 times cleaning per pass as compared with any other solar panel cleaning device.

- **Availability for domestic sector:**
  The robotic cleaning devices available for large scale solar PV module setup are neither compatible nor affordable for domestic sector. Hence focus of this project is to develop robotic cleaning device which fulfill the domestic sector needs.

III Methodology:

1. Application of Design of Experiment (DOE) to find the best cleaning method:

2. Hardware

3. Operation

1. Application of Design of Experiment (DOE) to find the best cleaning method:

We conducted design of experiments to find out best cleaning material for brush and wiper. The following calculations depicts the results obtained from the practical experimentation.

Table 1: Nomenclature:

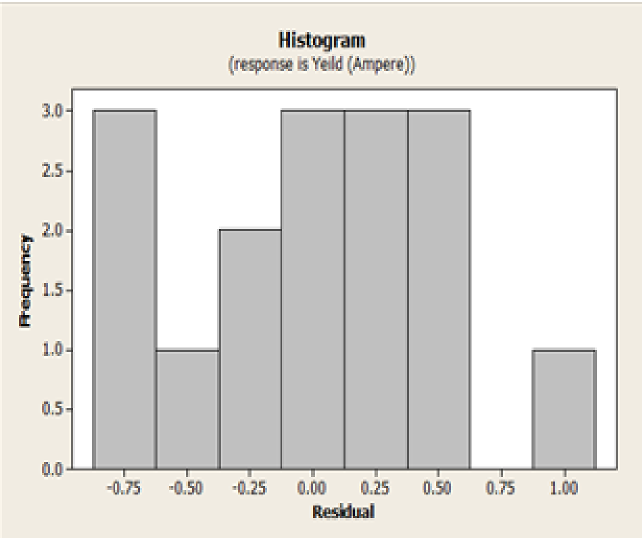
Sr. No.	Specification	Symbols
1	High level	1
2	Low level	-1
3	No relation	N
4	Residual error	ἐ
5	Factor	X
6	Probability	P
7	Factor effect	B
8	Total effect	ΔY

Yield = Current generation (290W PV module)

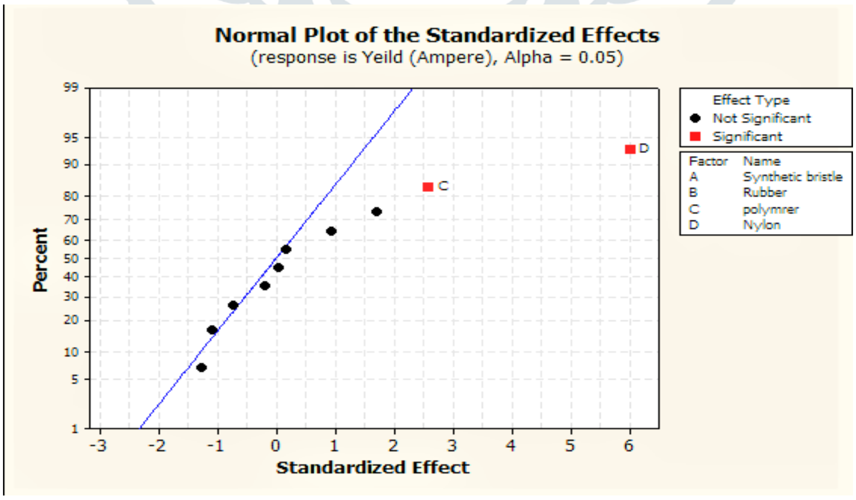
The small value of P shows that significance between two independent factors is high. Fractional factorial still with optimize setting taking four different types of cleaning solar panel and by using DOE procedure find a adequate cleaning method.

Table 2: Factors and its interaction with its probability

Terms	Effect	Coef.	SE.coef	T	P
Constant	7.0387	0.2339	30.09	0.000	
Synthetic bristle	0.4609	0.2305	0.2426	0.95	0.386
Rubber	0.7944	0.3972	0.2339	1.70	0.150
polymer	1.2109	0.6054	0.2339	2.59	0.049
Nylon	2.8114	1.4057	0.2339	6.01	0.002
Synthetic bristle*Rubber	0.0769	0.0385	0.2426	0.16	0.880
Synthetic bristle*polymer	-0.0937	-0.0468	0.2426	-0.19	0.855
Synthetic bristle*Nylon	-0.3597	-0.1798	0.2426	-0.74	0.492
Rubber*polymer	0.0234	0.0117	0.2339	0.05	0.962
Rubber*Nylon	-0.5076	-0.2538	0.2339	-1.08	0.327
polymer*Nylon	-0.5926	-0.2963	0.2339	-1.27	0.261



Graph 1: Histogram of Frequency vs. Residual



Graph 2: Normal plot Std. effect vs. Percentage

Table 3: Analysis of Variance for Yield (Ampere) (coded units):

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	4	44.1133	40.2150	10.0537	12.76	0.008
Synthetic bristle	1	3.0224	0.7114	0.7114	0.90	0.386
Rubber	1	2.4730	2.2718	2.2718	2.88	0.150
Polymer	1	5.9785	5.2783	5.2783	6.70	0.049
Nylon	1	32.6394	28.4535	28.4535	36.10	0.002
2-Way Interactions	6	2.9994	2.9994	0.4999	0.63	0.704
Synthetic bristle*Rubber	1	0.0134	0.0198	0.0198	0.03	0.880
Synthetic bristle*Polymer	1	0.0254	0.0294	0.0294	0.04	0.855
Synthetic bristle*Nylon	1	0.5268	0.4332	0.4332	0.55	0.492
Rubber*Polymer	1	0.0009	0.0020	0.0020	0.00	0.962
Rubber*Nylon	1	1.1686	0.9277	0.9277	1.18	0.327
Polymer*Nylon	1	1.2643	1.2643	1.2643	1.60	0.261
Residual Error	5	3.9405	3.9405	0.7881		
Lack of Fit	4	3.9405	3.9405	0.9851		
Pure Error	1	0.0000	0.0000	0.0000		

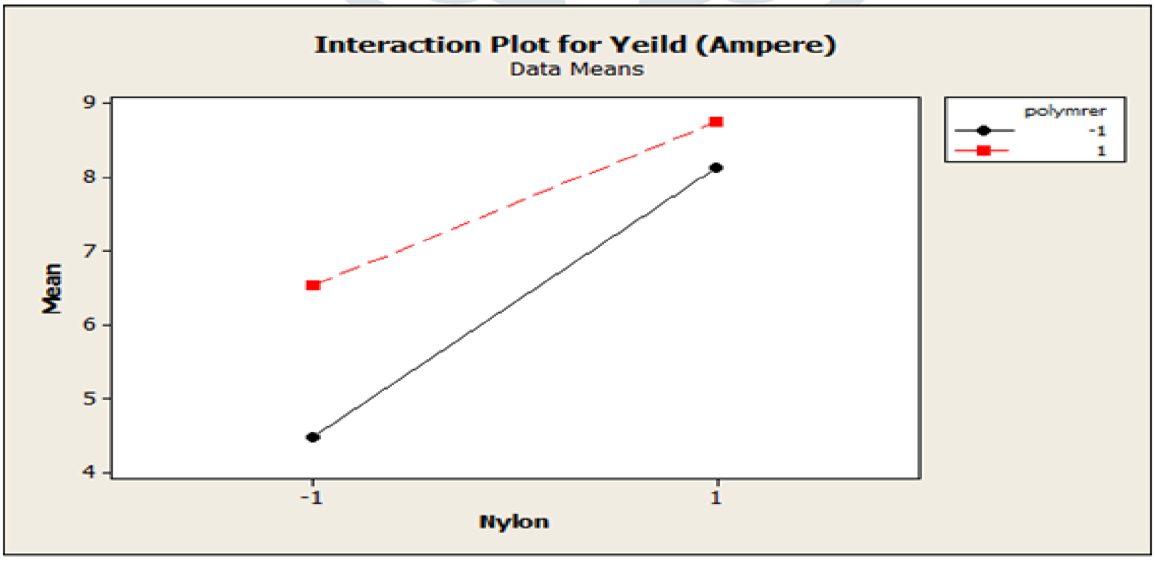
Total Result **15** **51.0531**

Result:

Observation	Std Order	Yield (Ampere)	Fit	SE Fit	Residual	St Resid
6	6	8.95600	7.94456	0.73979	1.01144	2.06R

Table 4: Distribution of components

↓	C1	C2	C3	C4	C5	C6
	Synthetic bristle	Rubber	polymrer	Nylon	Yeild (Ampere)	StdOrder
1	-1	-1	-1	-1	3.254	1
2	1	-1	-1	-1	4.750	2
3	-1	1	-1	-1	4.965	3
4	-1	1	-1	-1	4.965	4
5	1	-1	-1	1	7.231	5
6	-1	-1	-1	1	8.956	6



Graph 3: Interaction graph

2. **Hardware:**

The body of the aspect is mainly made of aluminum alloy, this ensures the strength to weight ratio and provides resistance to any climatic conditions. Wheel pairs are mounted on outer frame using nut-bolt which gives the rolling motion along the periphery of panels. Similarly inner frame consists of soft nylon brush and two wipers on each ends of the frame. This VBV(Viper Brush Viper) arrangement provides 3X cleaning which is capable of removing any type of unwanted foreign particles from the solar panels. The motion of the inner frame is guided by linear actuating motor. Parking station is provided at the ends of panel setup where ASPECT can rest when not in operation.

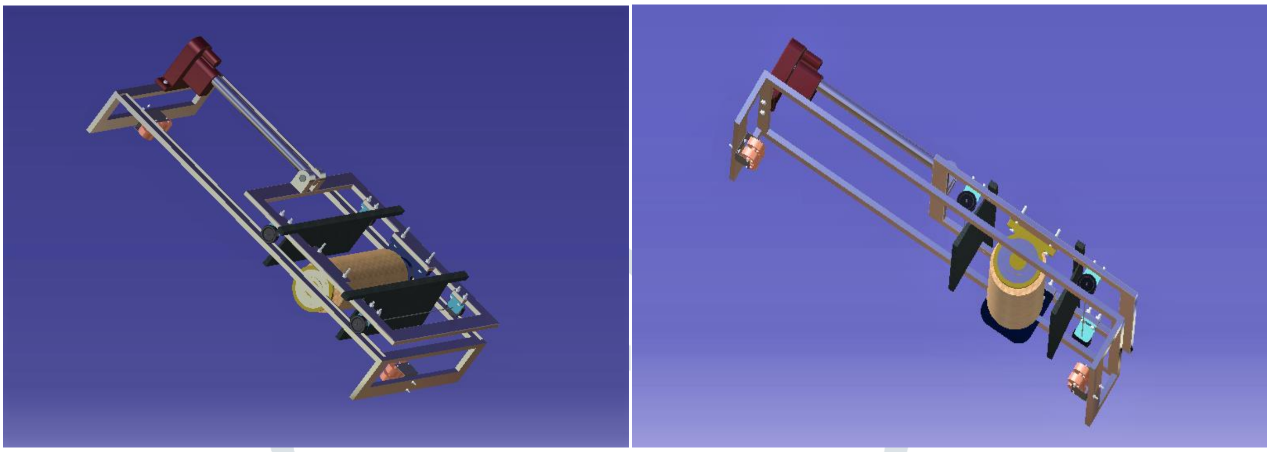


Figure 2: CAD Model of ASPECT on DS Catia v5

Table 5: MAJOR COMPONENTS OF ASPECT

Components	Specification
Outer Frame & Inner frame	Al alloy
Wheel pair on outer & inner fame	32mm (diameter)
Self-locking wheel	28mm(diameter)
Linear actuating motor	12V , stroke length = 600mm
Dc motor 1	12V , 300mA
Dc motor 2	12V , 600mA
Cleaning brush and Viper material	Nylon-66
Microcontroller	Arduino Uno
Battery	12V , 14Ah
Wires	For connection

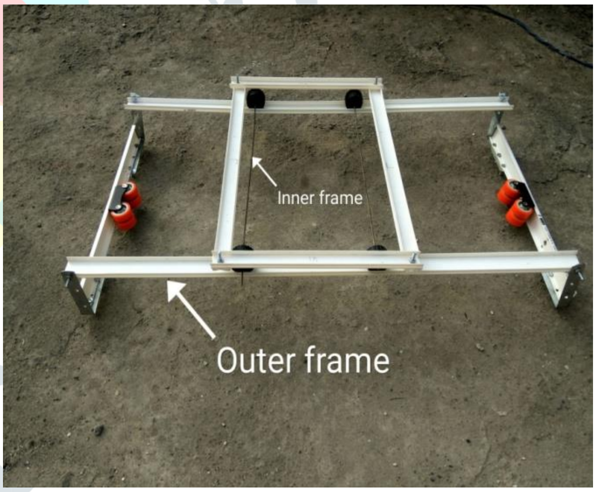
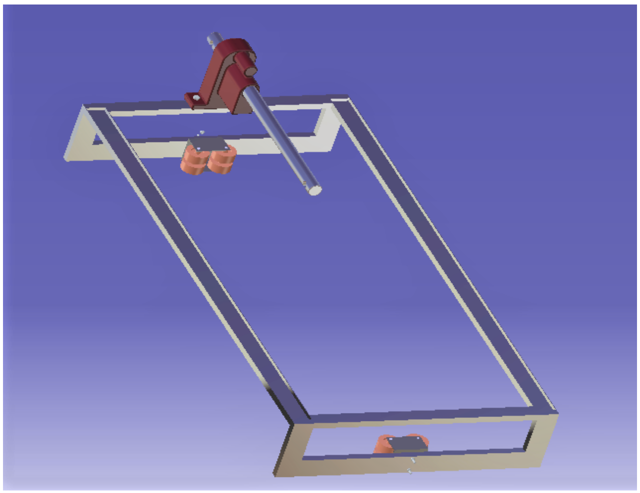


Figure 3: Basic prototype of ASPECT

3. Operation:

Initially, the ASPECT rests upon the guide ways provided on the parking station. The ASPECT is programmed to activate at a predetermined time after which it embarks the cleaning process. Firstly, the microcontroller signals the DC motor via AT mega 328 connected to the wheels of the outer frame to glide over the solar panels from the parking station. After 10 rotations and covering 300mm distance on the solar panel, the microcontroller signals the DC motor to stop. Now, brush's motor and linear actuating motor are simultaneously signaled to start the cleaning operation along the longitudinal direction of the panel and covers the entire width of the panel. Then, the linear actuating motor retracts its arm causing the inner frame to traverse to its original position. Similar process is carried out to clean the entire solar panel setup.



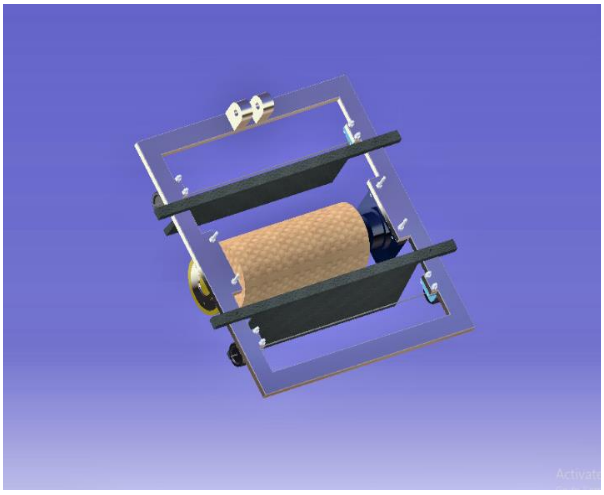


Figure 4: CAD model of Outer frame with linear actuating motor **Figure 5: CAD model of Inner frame with cleaning system**

Table 6: Power consumption of electronic components:

Sr. No.	Components	Specification	Cost(INR)	Consumption(mA)
1	DC Motor	12 V , 300mA , 250 rpm	450	300
2	Linear actuating motor	12V, Stroke length 600mm	1200	1000
3	Arduino Uno	ATmega 328	550	8
4	Battery	12V 14Ah	890	_

IV. Results and discussion:

If a daily loss in solar conversion efficiency is 0.25. System receives average 8 sun hours per day .If the price for 1 KWh is Rs.8 (1 unit). Cost of cleaning solar array for domestic scale is Rs.400 (for particular time).

Using formula,

Solar array should be clean = $\eta = (2V/\mu su\beta)$ = 4 days.

Where,

V = Cost of cleaning solar array, μ= daily loss in solar conversion efficiency, s= sun hours per day,u=solar panel setup capacity , β= charges on unit.

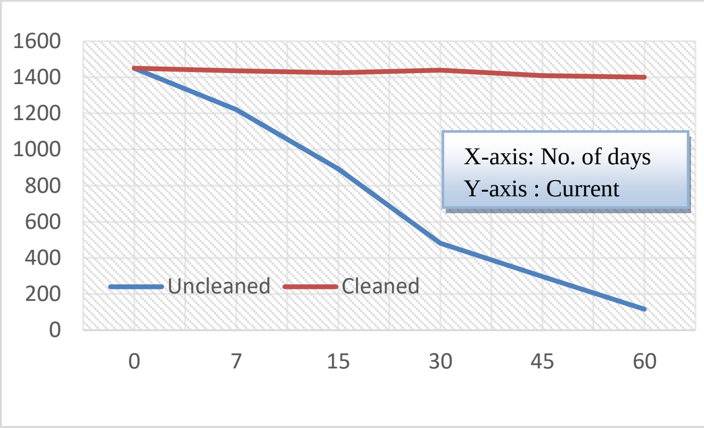
Here,

From this example we can see a lot of electricity is generated from solar panel setup. If the solar panels not maintain properly then it will be a great loss of the energy. There device i.e. ASPECT mention in above research paper is help the domestic sector to maintain their solar panel efficiency. And give its maximum output.

From the results obtained for the uncleaned panel we conclude that there is steep decline in current output from the solar panels as the duration of days increase. By implementing the ASPECT to clean the solar panel the current output from the solar panel remains steady.

Table 7: Observed values of current output w.r.t No. of days

	Current Output (Ampere)	
No. of Days	**Uncleaned**	**Cleaned**
7	1450	1448
15	1221	1448
30	893	1445
45	482	1447
60	298	1448



Graph 4: Graphical representation of effect of dust on solar panel output

(*These calculations are for specific solar conversion efficiency and accumulation of dust in µg/m^3)

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