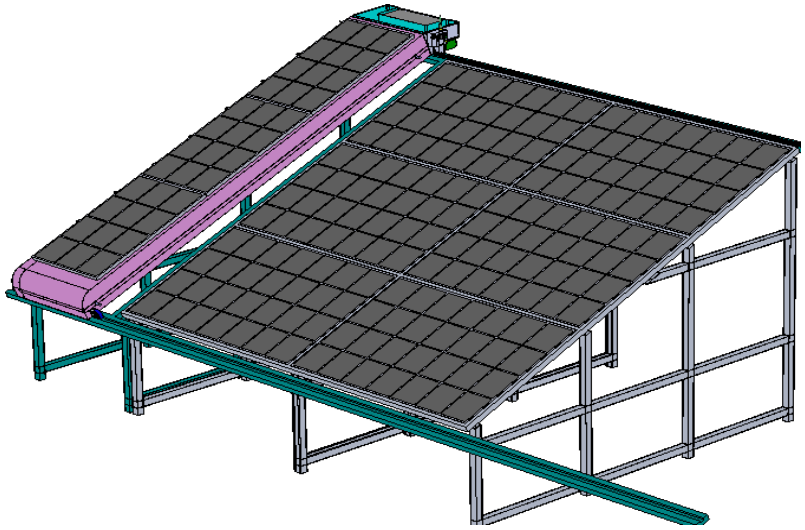


Automated Solar Panel Cleaning Robot

Product Development Project Report

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Project Report
On
Development of Automated Solar Panel Cleaning Robot

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1. Introduction

Photovoltaics (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photoelectric effect; a phenomenon in which electrically charged particles are released from or within a material when it absorbs electromagnetic radiation. A photovoltaic module is a packaged, connected assembly of solar cells. Each module is rated by its DC output power under standard test conditions (STC), and typically ranges from 100 to 320 watts. With a same rated output power, the area of a module varies depending upon the conversion efficiency of PV system used.

One of the most important factors in solar energy technologies' applications is the amount of solar energy incident at a location. The amount of solar energy incident per unit area per unit time is referred to as irradiance (measured in kWh/m^2 per day or kWh/m^2 per year). Solar radiation consists of a direct (direct beam radiation) and a diffuse component. For the purposes of different types of applications, solar radiation data is given as Global Horizontal Irradiance (GHI) and Direct Normal Irradiance (DNI). The various components of solar radiation is illustrated in **Figure 1**

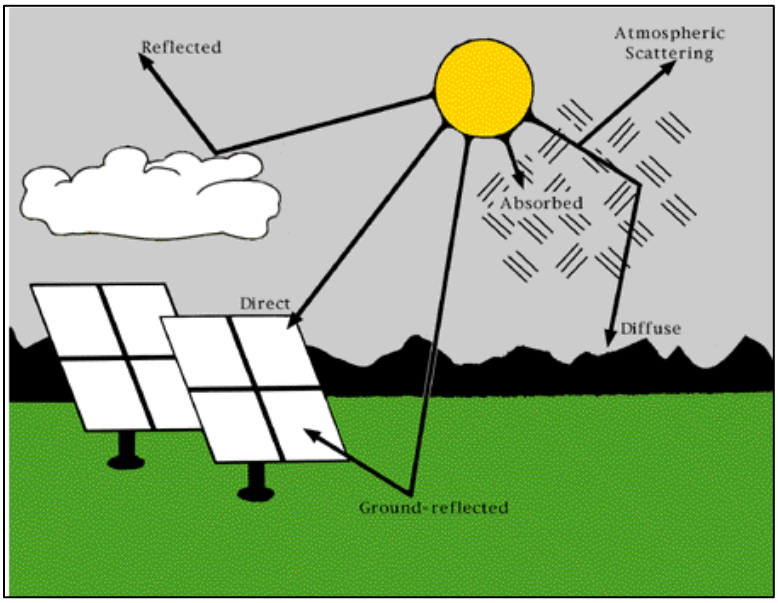


Figure 1: Illustration of Solar Radiation

1.1. Problem Statement

For the conversion of solar radiation to electrical energy, the amount direct and ground-reflected solar radiation is a very crucial element. Environmental pollution, accumulation of dust and dirt on the surface of PV panel interferes and creates obstacles for the solar radiation to reach PV cells.

Solar panels are normally designed to produce the ideal output or optimum yield for about 25-30 years [2]. The factors that influence optimum yield can be classified into two categories, namely, variable and invariable parameters. The parameters that can be changed provide design flexibility to respond to varying installation requirements, while parameter that is invariable need to be adapted as default.

The characteristics of a PV module can be demonstrated by power-voltage or current-voltage curves. **Figure 2** shows that PV output power is dependent on solar irradiance and cell temperature. Low irradiance leads to low power, and high temperature causes a reduction in output power. Furthermore, for each curve of the PV module, there is a point on the curve at which the PV module delivers maximum power to the load. This point is known as maximum power point (MPP).

In addition to these factors, the amount of energy delivered by a PV module is dependent on other factors such as the reliability of other components of the overall system and local environmental conditions.

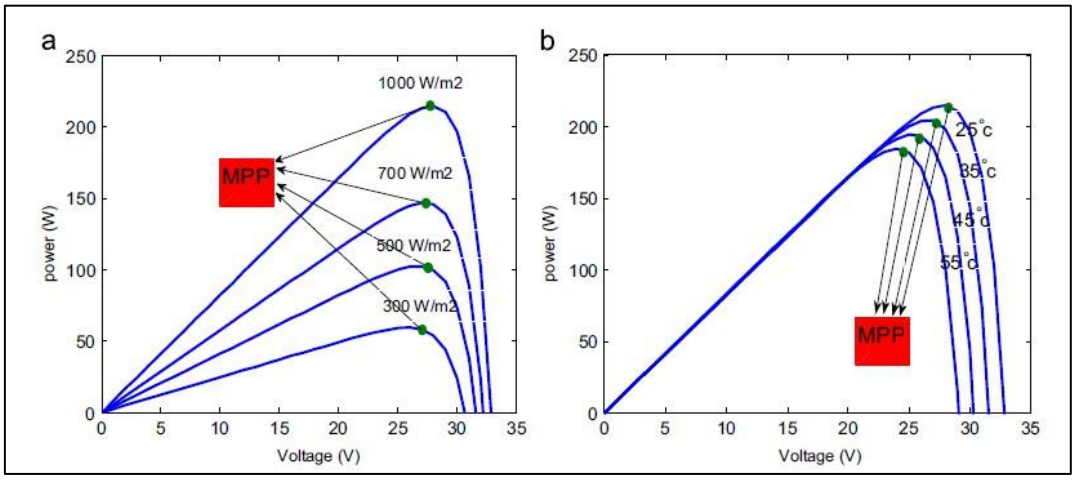


Figure 2: (a) Power-Voltage characteristics of a PV and location of the MPP for different irradiances at 25°C, (b) different temperatures at an irradiance of 1000 W/m^2.

Appropriate installation (orientation, exposure, sun-trackers) to maximize solar insolation can potentially ensure sustained yield. However, these are vulnerable to, often overlooked, on-site omnipresent practicalities such as deposition of dust, bird-droppings and water-stains (salts) which can significantly degrade the efficiency of solar panel performance. For PV installations module efficiency is further reduced by 10–25% due to soiling (dust and debris)

The amount of accumulated dust on the surface of the PV module affects the overall energy delivered from the PV module on a daily, monthly, seasonal and annual basis. Sanaz Ghazi in 2014 investigated the pattern of dust distribution in different parts of the world as indicated in **Figure 3** and it was found that the Middle East and North Africa have the worst dust accumulation zones in the world.

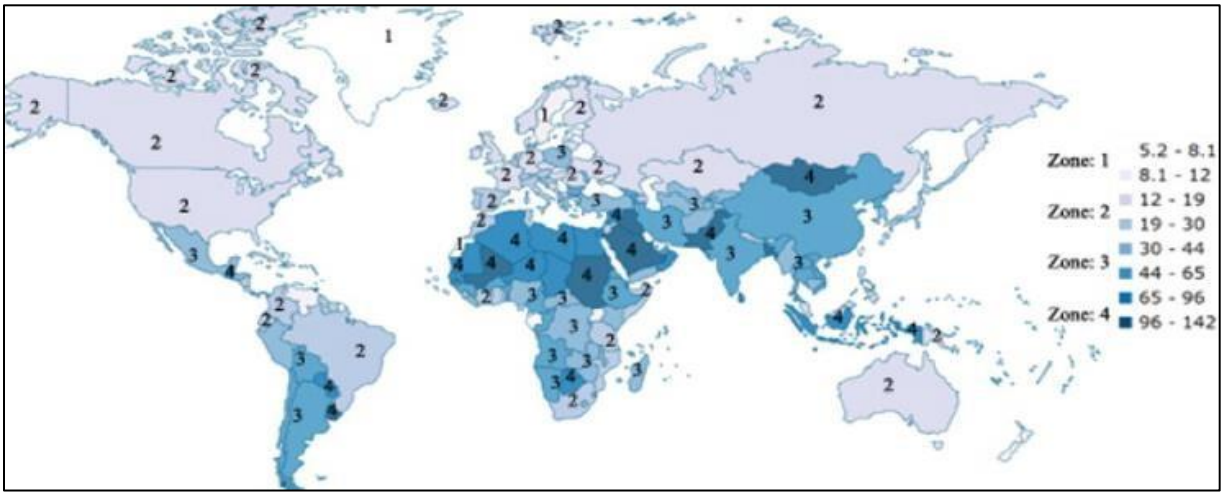


Figure 3: Dust intensity around the world

The characteristics of dust settlement on PV systems are dictated by two primary factors that influence each other, viz., the property of dust and the local environment. The local environment comprises site-specific factors influenced by the nature of prevailing (human) activities, built environment characteristics (surface finishes, orientation and height of installation), environmental features (vegetation type) and weather conditions. The property of dust (type – chemical, biological and electrostatic property, size, shape and weight), is as important as its accumulation/aggregation. Likewise, the surface finish of the settling surface (PV panel) also matters. **Figure 4** Shows factors influencing dust settlement.

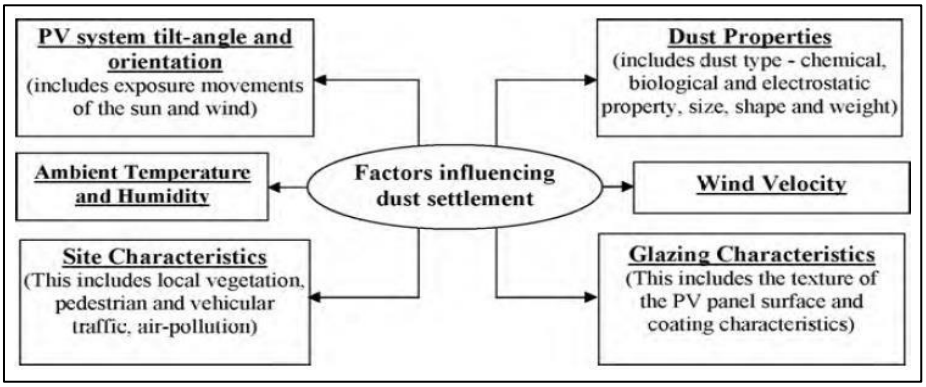
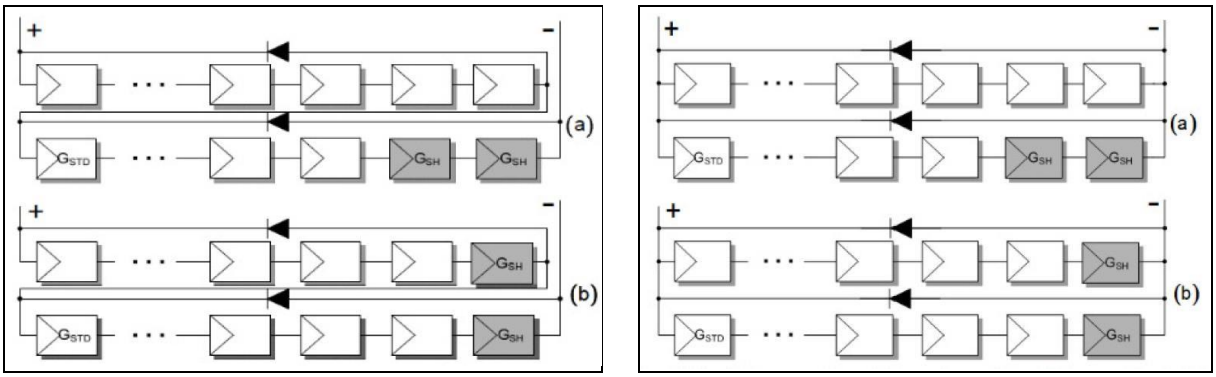


Figure 4: Factors influencing dust settlement

A specific study shows that there is a significant reduction in power output of solar PV array even if only a few modules are shaded due to dust accumulation (partial shading). An experiment to verify the results by partial PV shading on a number of PV cells connected in series and/ or parallel with and without bypass diodes shows a considerable reduction in output power generated and the amount of loss greatly depends upon which PV modules are shaded.



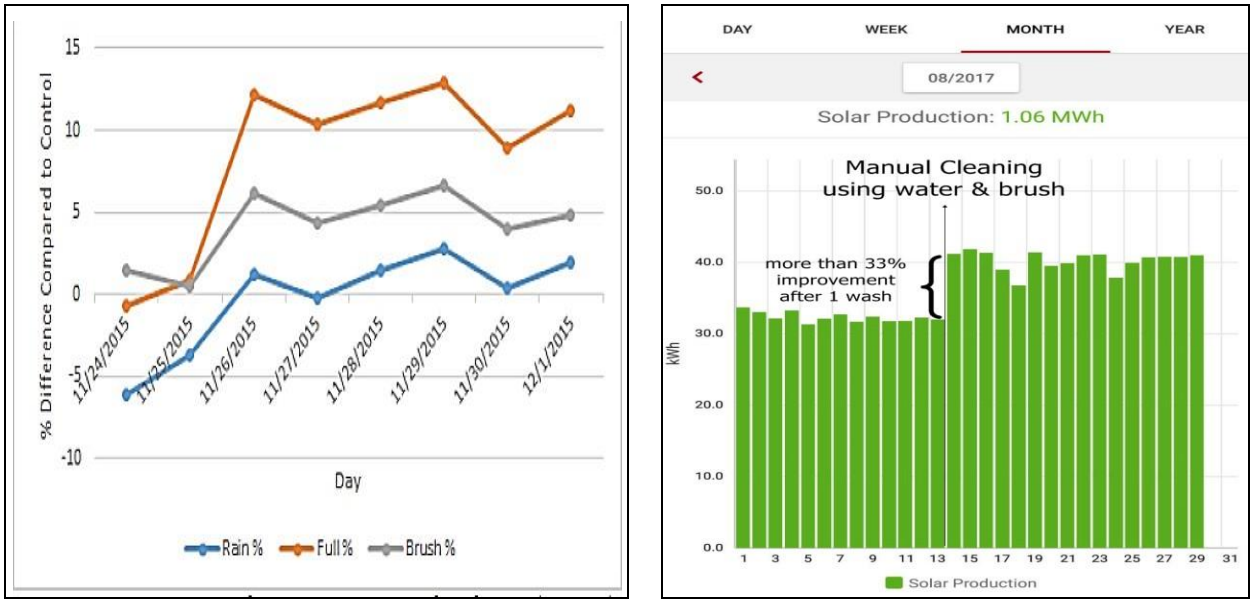
(A) (B)

Figure 5: (A) Series connection of two submodules (a) Two cells shaded in one submodule, (b) one cell shaded in each module

(B) Parallel connection of two sub-modules (a) Two cells shaded in one submodule, (b) one cell shaded in each module

The maximum power reduction in modules connected in series as shown in **Figure 5 A (a)** and **(b)** are 50% and 70% whereas the maximum power reduction in modules connected in Pharrell as shown in **Figure 5 B(b)** is same as that of **Figure 5 A(b)**, that is by 70%.

Common order of magnitude for losses due to soiling can be estimated between 3-8% but can go up to 30-40% in dry and sandy climates. A comprehensive study on the effect of dust and dirt accumulation on solar PV performance had been carried out by many researchers.



(a) *(b)*

Figure 6: Increase in power output immediately after cleaning of PV panels (a) A study conducted at Santa Clara University in 2015, (b) Solar Energy production report generated for month of August 2017 by private owner in Israel

A particular study shows 10% increase in energy generation immediately following the cleaning of the solar panels as can be seen in **Figure 6 (a)**, similar study shows almost 33% gain the power output immediately after full cleaning **Figure 6 (b).**

Looking at the data presented by the researchers the following conclusions can be drawn.

- ✓ The amount of accumulated dust on the surface of the PV module significantly affects the overall energy delivered from the PV module on a daily, monthly, seasonal and annual basis. Based on the local environment, pollution and dust level the reduction in power output from solar panels can be seen from 4% to 40% in some severe conditions.
- ✓ Two interdependent parameters that affect the characterization of soiling accumulation on solar panels, the property of dust and the local environment.

- ✓ Sometimes solid patches such as leaves, bird-droppings and dirt patches that block some cells of a PV module but not the whole have a severe effect on PV modules.
- ✓ The type of dust and particles not just hinder the sun radiation but can also damage the panel surface permanently in the form of scratches, erosion, corrosion, and delamination
- ✓ In order to maximize the power output from the installed PV systems, the solar panels must be fully cleaned periodically with appropriate cleaning methods.
- ✓ The cleaning frequency is based on the type and rate of dust accumulation, which is based on local environmental conditions. General recommendation of mitigation measures against (likely) impact of dust accumulation on PV performance is proposed by researchers in this field as tabulated in Error! Reference source not found. in **Appendix-**Error! Reference source not found.
- ✓ Thus, the regular cleaning with effective operation and maintenance practice play a huge role in keeping the higher power output from the installed PV set-up.

1.2. Review of Current Situation

The developments in automated cleaning systems have emerged since 2000. There are several methods available, and few are commercialized too. They can be compared based on cost, ease of operation, cleaning performance and cleaning rate. Several automation efforts have been tried and tested by researchers.

Few systems are based on portable robots with cleaning head that can autonomous clean the panels based on pre-programmed sequence, and few are remotely operated. However, it still needs human intervention to start the operation and while moving from one panel array to another. Other types of the robotic system comprise two motorized trolleys at the edges of panels, which provide horizontal motion, and a cleaning head driven by a belt and pulley system for vertical motion. Cleaning head comprises rotating cylindrical brushes to scrub the PV panel and a scraper to remove the dirt solution. Some other types of systems use moderately pressurized waterjets that can wash-off dirt, dust and even bird-drops but involve high water consumption. Also, they require demineralized water in order to avoid hard scaling and mineral deposits, which may damage PV panels permanently.

Other techniques involve electrostatic discharge curtain, which comprises of surface electrodes energized by phased voltages that produce an electrostatic travelling wave for lifting and transporting dust particles.

Thus, there are distinct solutions available to address a specific need, which may have limited areas of applications. Many remain as prototypes that are very good demonstrators of high technology but cannot be introduced in the market. This motivates us to devise an automatic PV panel cleaning system for large solar array field, that will minimize or eliminate all possible shortcomings in the systems presently developed and to give a value-added proposition to solar PV panel cleaning market

1.3. Project Goal

We are proposing an automated system for cleaning of the large-scale solar array. Our device will boost the efficiency of SPVs by increasing the energy output of solar panels in a quick and cost-effective manner.

The automation of the system will also reduce the risk of an operator injuring himself in a high voltage environment. A successful device will clean multiple solar panels in an array and increase their efficiency. We aim to provide a non-wasteful approach to cleaning commercial-sized solar panel systems by using minimal amounts of water and power while requiring little to no maintenance. This system will clean a single row of panels periodically or as per need. It will also be able to identify and clean specifically affected panels, which show drastic performance reduction due to dust accumulation.

1.4. Broad Definition of the Concept

The main functions that the proposed system should perform are,

1. Detection of dirt and dust level on PV Panels
2. Schedule the cleaning operation and communicate to end user for approval
3. Actuation of Cleaning System as per approved cleaning schedule
4. Maneuver carrier module, kinematic module and cleaning module
5. Perform cleaning operation as per predefined cleaning sequence.
6. Avoid obstacles if any during cleaning operation
7. Ensure safety of operation
8. Complete cleaning operation and dock the system to its home position

The proposed system may consist of following modules

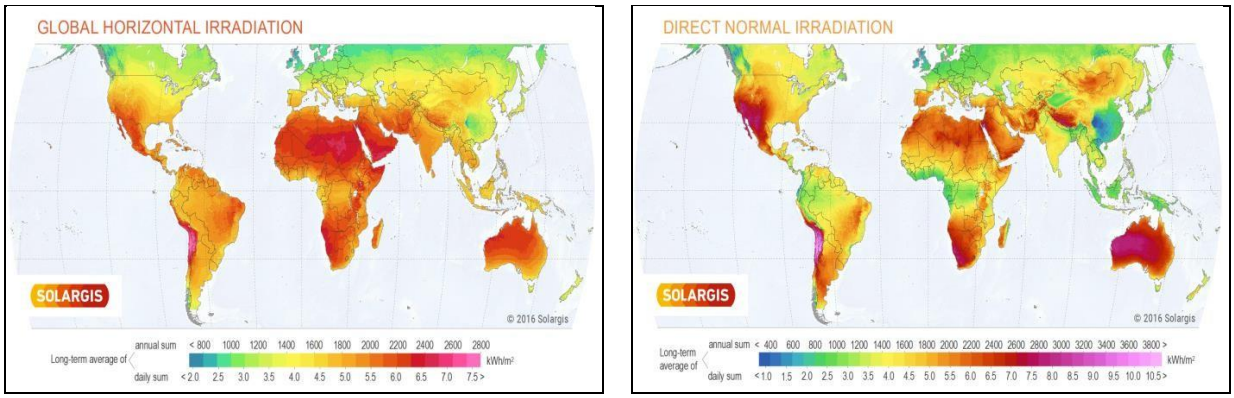
- ✓ Centralized Command and Control Unit
- ✓ Dirt and dust level detection and sensing sub-system
- ✓ Carrier cum Kinematic Module
- ✓ Cleaning sub-system
- ✓ Fall or Collision Avoidance System
- ✓ Communication sub-system
- ✓ Operator interface

2. Business Environment

The following section is going to discuss the potential target market as well as market size for the PV automatic cleaning system. Furthermore, economic and regulatory constraints will be presented with relation to PV cleaning system.

2.1. Target Market

The preliminary criteria of identification of target market are based on geographically favourable regions with highest Annual Solar Irradiance availability; which also shows a high level of dust and low precipitation as can be seen in **Figure 3** in section **1.1** and **Figure 7** below**.**



(a) (b)

Figure 7: (a) Global Horizontal Irradiation (GHI) (b) Direct Normal Irradiation (DNI)

The second and the most factual criteria are based on the scale of solar PV installed capacities and prospective growth is selected region.

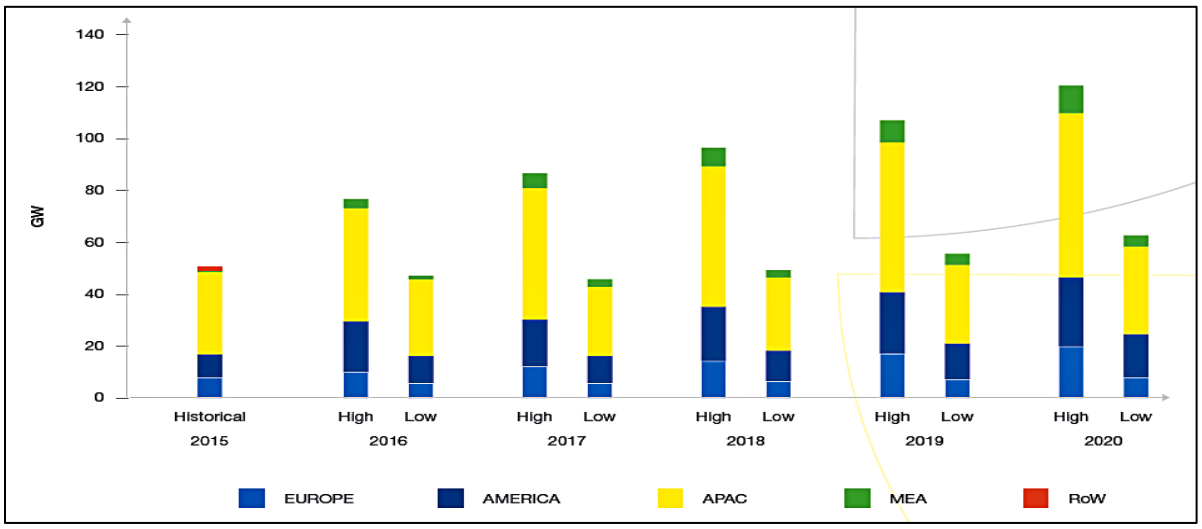


Figure 8: Global Annual solar PV market shares for high and low scenarios until 2020

As **Figure 8** shows the Asia Pacific region has shown significant share in installed and projected solar PV Installation capacities. Out of top three solar PV markets in the world, China, USA and India have shown substantial contribution and indicate that China will lead the solar PV sector followed by UAS and India as the third biggest solar PV market in the world. This growth is due to favourable government's renewable energy policies.

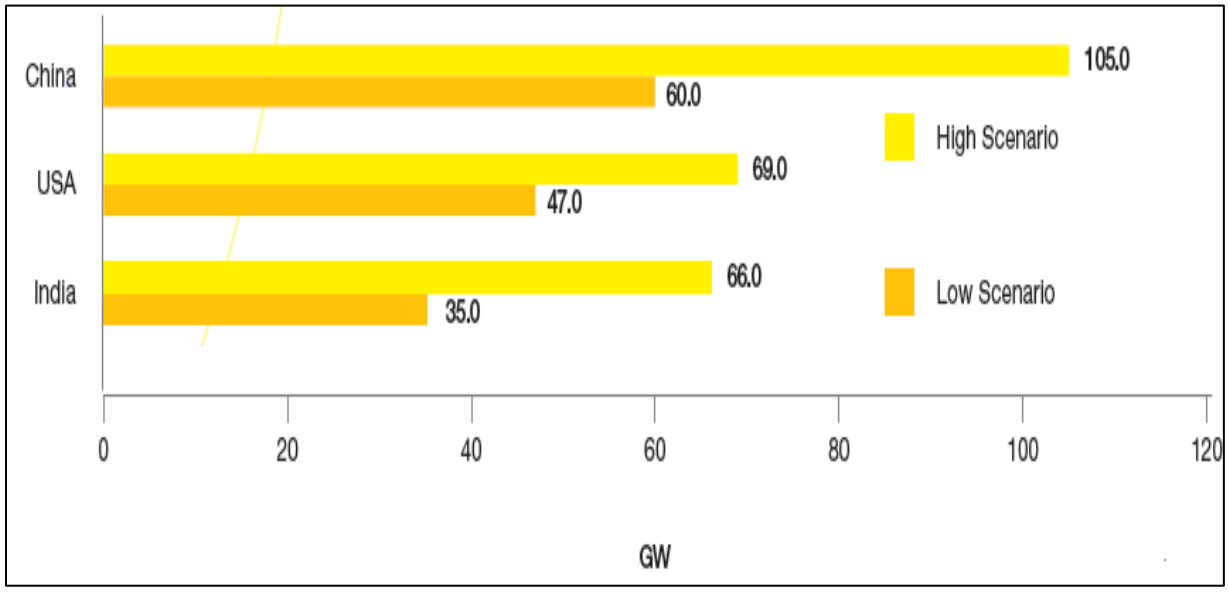


Figure 9: Top Three Market's Solar PV additions from 2016 - 2020 with high and low scenarios

Thus, based on **Figure 8** and **Figure 9** we consider China and India as our prime market regions. Among these regions, we have identified three separate potential market segments for automated solar PV panel cleaning system. Each market offers different advantages and drawbacks. The main criterion for our potential market is the ratio of the system's unit cost relative to the number of panels to be cleaned.

The first market segment consists of residential homeowners. In this case, due to low capacity and few numbers of panels, cleaning by automated means is impractical and expensive. So the system cost should be extremely low which we believe impossible within a reasonable number of iterations. Our second market segment is large-scale commercial installations. Many commercial and industrial companies are becoming increasingly focused on sustainable energy solutions as a basis for directly serving or offsetting their energy consumption. The third significant segment is multiple acre solar farms, which consist of massive solar panel arrays.

Large commercial scale and utility-scale solar PV systems are intended for higher energy generation ranging from hundreds of MWh to GWh energy output. To maximize the power output and to make the profitable investment, these plants must be maintained to exploit its full capacity.

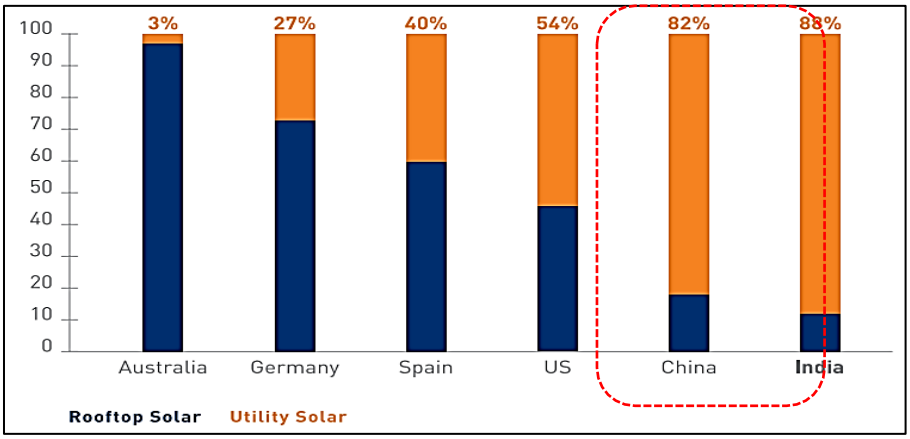


Figure 10: Share of utility-scale solar vis-à-vis rooftop solar

As indicated in **Figure 10,** utility-scale solar PV has the highest share as compared to the rooftop solar PV installation in the target market.

The conventional means of cleaning of such a large numbers of PV panels is highly labour intensive, time-consuming and costly. Moreover, it invites the use of additional resources, high water

consumption and trained work force. Automation can surely reduce the above-mentioned limitations associated with manual cleaning operations

Based on the above facts, we consider China and India as the prime market segment in terms of region and within this segment, large-scale commercial and utility-scale PV installations are our prime target market by scale; for the proposed automated cleaning system.

2.2. Market Size

The expected market size is proportional to the estimated power generation capacity, which is relative to the number of PV panels installed, within the target regions. With an installed capacity greater than 237 GW worldwide and annual additions of about 40 GW in recent years, the worldwide growth of photovoltaics has shown an exponential growth during 2000–2015. During this period, solar PV evolved from a niche market of small-scale applications to a mainstream electricity source, as can be seen in **Figure 11**

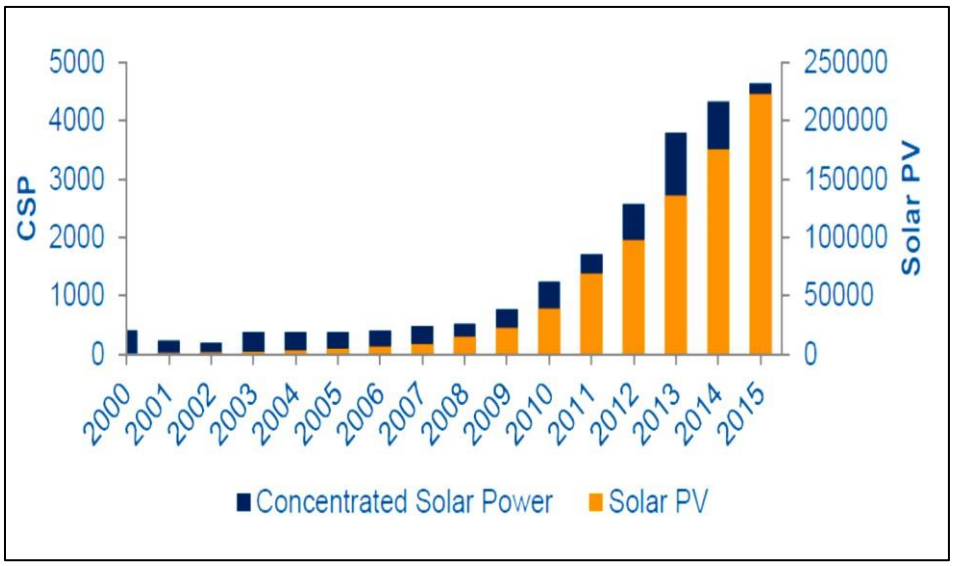


Figure 11: World Solar Energy market development from the year 2000 to 2015

Stepping forward a year 2020 is expected to see a Low Scenario of 490 GW, a High Scenario of 716 GW, and a Medium Scenario of 613 GW.

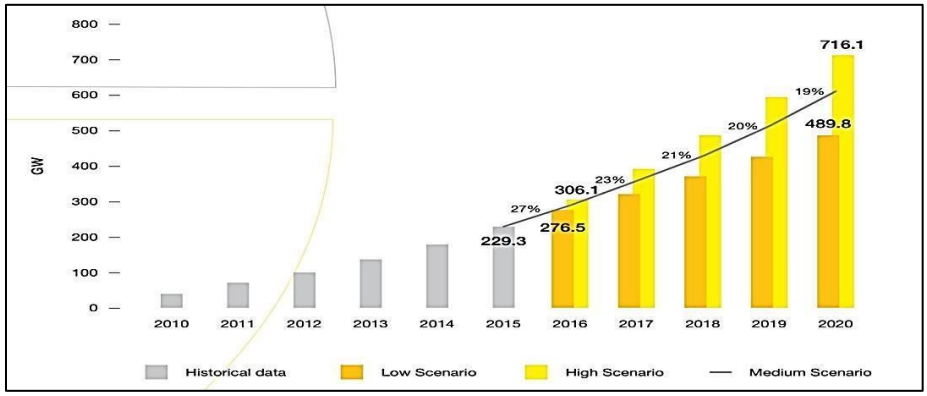


Figure 12: Global Total Solar PV Market Scenarios until 2020

Many emerging economies have an excellent solar resource and have adopted policies to encourage the development of the solar industry to realize the benefits on their economies and on improving energy security, as well as on the local and global environment.

In addition, solar installations can be built relatively quickly, often in 6–12 months, compared to hydro and fossil fuel projects that require more than 4–5 years to complete. This presents a major incentive in rapidly growing, emerging markets with a high unmet demand and the urgent need for power. Assuming that PV technology prices continue to fall relative to competing sources of electricity, the market penetration rate of utility-scale solar power projects can be expected to continue growing rapidly, including in emerging markets.

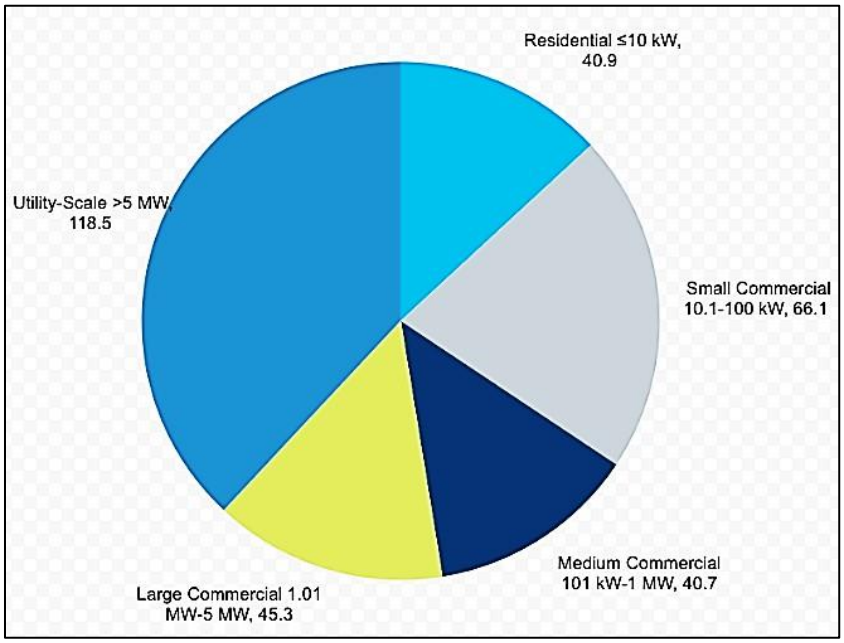


Figure 13: Cumulative demand by segment till 2021

In the segment-wise expected distribution of solar PV Installations till 2021, a large-scale commercial and utility-scale segment together will have more than 51% market share as can be seen in **Figure 13**. Specific to the target country, as of March 31, 2017, India had installed 12.2 GW of utility-scale solar PV capacity. There will be 44 GW additions in utility-scale solar PV installation capacity until 2021 in India alone. Nearly 60% of total new capacity addition is expected to come in three southern states of Telangana, Andhra Pradesh and Karnataka. If taken into account, China's utility-scale capacity growth, a huge market size can be anticipated in near future.

Assuming the pessimistic low scenario of installed capacity in China and India utill 2020, as can be seen in **Figure 9,** the overall estimated capacity will be 95GW. Out of this, assuming 80% capacity is belongs to utility-scale solar PV plants (refer **Figure 10**). We estimate just 10% share in the available market that is around 7.6GW. Based on the calculation as shown in **section 2.3**, **Table 1** and **Table 2,** the cost for cleaning for 7.6GW translated to 123.12 Million USD for manual cleaning per year. This clearly indicates the good business potential for development of novel automated cleaning system.

2.3. Economic Constraints and Success Criteria

There are a number of factors influencing the costs of solar systems cleaning. Each solar facility has unique characteristics that are driven by site location; PV panels array arrangements and local environmental conditions. Therefore, while cleaning the panels would increase panel performance, the cost of cleaning would need to be accounted for in the gross outcome of the solar panel's economic benefits. In order to understand the economic impact of dusty PV panels on sellable KW power, we performed calculations for estimated cost of cleaning as well as loss due to dust accumulation have been performed.

Table 1: Assumptions and preliminary data for calculations of losses due to PV panel soiling

Parameter	Qty	Unit
Available Radiation level	1000	W/m^2
Number of Effective radiation Hours /day	8*	Hrs
Number of Effective radiation days/year	250*	days
~Performance degradation due to dust accumulation	30*	%
~Sellable Price of Solar Power/KWhr (4.4 INR/KW)	0.066**	USD/KW
~No. of Cleaning Cycles Desired/year	6*	Nos
PV Panel Length	2*	m
PV Panel Width	1*	m
PV Panel Surface Area/panel	2*	m^2
Number of panels per 1KWhr capacity	3*	Nos.
SPV surface area per 1KWhr capacity	6	m^2
Cost of Manual Cleaning /KWhr capacity (INR 30/1KW)	2.7*	USD/KWhr
Cost of Manual Cleaning /m2 PV surface area [19]	0.45	USD/m^2

* Figures are based on data collected form preliminary survey and interviews and data available on internet
** Present electricity charges (Approximately)per KW in India (Rs. 4.4/KW ~ USD 0.066/KW)
Currency exchange rate for INR to USD : 1INR~ 0.015USD as on 27 Sept. 2017

Based on the rated efficiency of solar panel, to generate 1KWhr power approximately $6m^2$ PV surface is needed. Apart from ~0.5% annual degradation in PV conversion efficiency in present commercial PV system, there are approximately additional 30% losses in efficiency due to soiling of PV panels in dry and hot arid conditions in the selected region of the target market.

Table 2: Sample calculations of cost of sellable power and cost of cleaning of PV panels

Parameters	Qty.	Unit
For 1,000KWhr (1MWhr) capacity Plant, nominal power output capacity	1,000	KWhr
Number of panels per 1,000KWhr Array	3,000	Nos.
SPV surface area per 1,000KWhr capacity	6,000	m^2
Cost of sellable solar power from 1MWhr capacity per hour	66	USD/hr
Cost of sellable solar power from 1MWhr capacity per hour (8 sunny hours per day)	528	USD/day
Cost of sellable solar power from 1MWhr capacity per hour (250 sunny days per year)	132,000	USD/year

Average Power Loss due to Soiling of PV panels considering 30% degradation in Power output	300	KWhr
Degraded capacity due to Soiling	700	KWhr
Cost of Sellable Power /1,000KWhr/year considering degradation from Soiling	92,400	USD/year
Loss of Income due to Soiling/year/1,000KWhr Capacity (uncleaned)	**39,600**	**USD/year**
Cost of Manual Cleaning/m^2 for 1,000KWhr Capacity/ unit cleaning	2,710	USD/cleaning
Cost of Manual Cleaning / m^2 for 1,000KWhr Capacity /Year	**16,258**	**USD/year**

Looking at above calculations it is pretty clear that for large-scale solar Installation (1MW and above) the dust and dirt accumulation has a significant impact on solar power generation from the installed capacity which can be translated into a significant economic loss (*approximately 40,000 USD/year for 1MWhr capacity*). Although there is a **definite NEED for periodical cleaning of PV panels**, the present cleaning methods are either impractical or uneconomical in case of large-scale solar PV installations.

Success Criteria:

The willingness to pay for an automated cleaning system is based on how much amount can be saved annually and what is the payback time on the investment made.

Based on initial assumptions, the acceptable time for return on investment (ROI) is 4 years.

Moreover if the purchase cost of automated cleaning system is kept to 50% of manual cleaning cost for a period of 4 year, which is come to around 32,500 USD (as can be seen in **Table 2**) there will be a significant saving in terms of time, efficiency and quality of cleaning that can be achieved using automated system compared to the manual cleaning.

2.4. Competitor Analysis

Table 3: Summary of commercially available industrial Solar PV panel cleaning system

#	Automated Cleaning System	Advantages	Limitations
1	Gekko solar	- Self-regulating and flexible uninterrupted cleaning operations.	1. Limitation of inclination up to 30 degrees. 2. Additional stresses on the surface due to gear, belt and vacuum system 3. Need external feed
2	Gekko solar farm	- Self-regulating and flexible uninterrupted cleaning operations.	1. Limitation of inclination up to 30 degrees. 2. Complex gear, belt system. 3. Need external feed
3	Wash Panel	- Able to clean dust and Bird Droppings.	1. Human intervention is required to start the operation and while moving from one row to another. 2. Need external feed
4	Greenbotics: GB1	- Able to clean dust and Bird Droppings.	1. Human intervention is required to start the operation and while moving from one row to another. 2. Need external feed
5	Ecoppia E4 cleaning system	- Effective Cleaning without use of water for Large Solar Fields especially dry and desert fields	1. Nor Suitable for humid and sticky dust removal 2. The possibility of scratches on panel surface due to dry dusting.
6	Nomadd	- Effective Cleaning without use of water for Large Solar Fields especially dry and desert fields	1. Nor Suitable for humid and sticky dust removal 2. The possibility of scratches on panel surface due to dry dusting.
7	Heliotex Automatic Solar Panel Cleaning Systems	- Water reaches to every part of solar PV module. - Helps in cooling of solar PV modules, which increases the efficiency.	1. Treated water required. 2. The filter has to be changed periodically. 3. Huge wastage of water or need of separate wastewater collection and treatment and recirculation system

Summary:

Competitor Analysis

Table 3 indicates the summary of existing automated cleaning system. In this section, we present the crucial limitations of the existing systems, and how our proposed system will eliminate those limitations.

- The existing systems clean entire PV panels in the array whether or not all panels are affected by dust. So these systems consume more power and need a huge amount of crucial resources like water. Sometimes only a few panels are significantly accumulated the dust than the rest of the array and selective cleaning is not possible in fully automatic mode by the existing solutions. We are proposing a system that will collect the data for degradation in power generation for the individual panel and also detect if the degradation is due to dust or not and finally selectively clean the dust affected panels only. This functionality enables an optimal use of power and resources for cleaning of panels.
- Most of the automated cleaning systems use treated water which is not suitable for the target market regions where there are limited water resources especially the country like India.
- The water-less cleaning system may be suitable for dry desert locations but are not suitable for humid and sticky dust and removal of bird-droppings. There is no single solution available to address cleaning for both types of dust. The target regions especially India have a variety of dust from industrial pollution, human activities, bird-droppings and different type of local environmental conditions. Thus there is a need of automated cleaning system which is suitable for both dry and humid dust removal with the minimum use of water and eliminates limitations associated with the existing cleaning systems.

3. Proposed Concept

3.1. Top Level System Diagram

In this concept, for every row of PV module array, there is a dedicated cleaning robot docked at a docking station, at the one of the end of array. The Robot is equipped with a on board sensor for visual imaging of affected panels, Microfiber based dry dusting motorized belt, motorized wipers for wet cleaning and wiping. It carries water reservoir, battery enclosure, and onboard solar panels for battery charging.

This motorized cleaning module move along a rigid metallic frame using Rack & Pinion assembly driven by DC motors, to ensure smooth movement with no direct load on the solar panels' surface. Each cleaning robot is powered by three electric motors – two motors driving the horizontal movement along the solar panel row, one motors powering the vertically rotating microfiber belt for dry dusting of panel surface.

The robot is also equipped with water pump and jets for spraying water for wet cleaning. A array of motorized wipers wet wipe the surface in order to remove sticky dirt deposition.

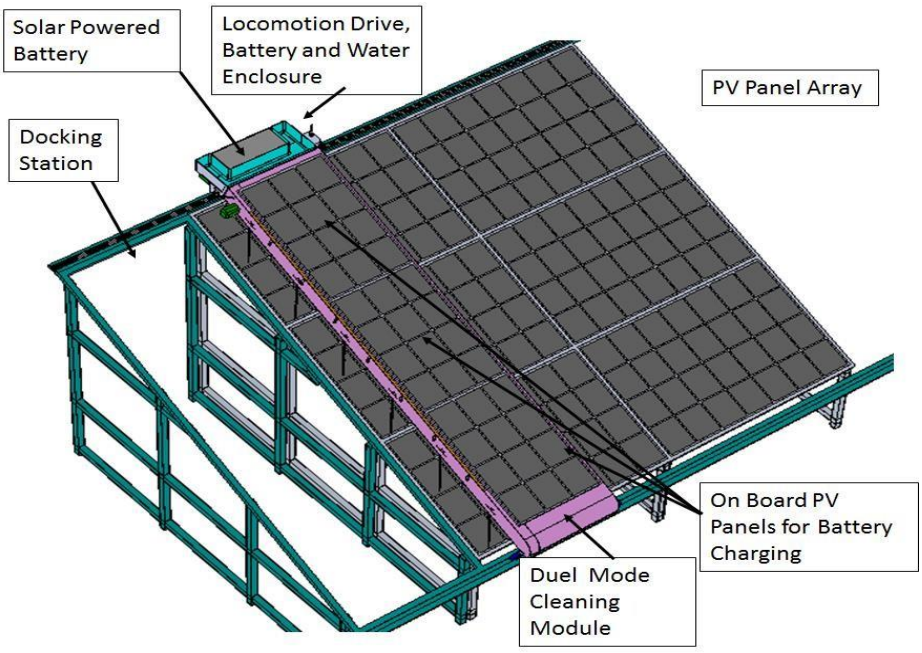


Figure 14: Top Level Architecture

3.2. System Architecture

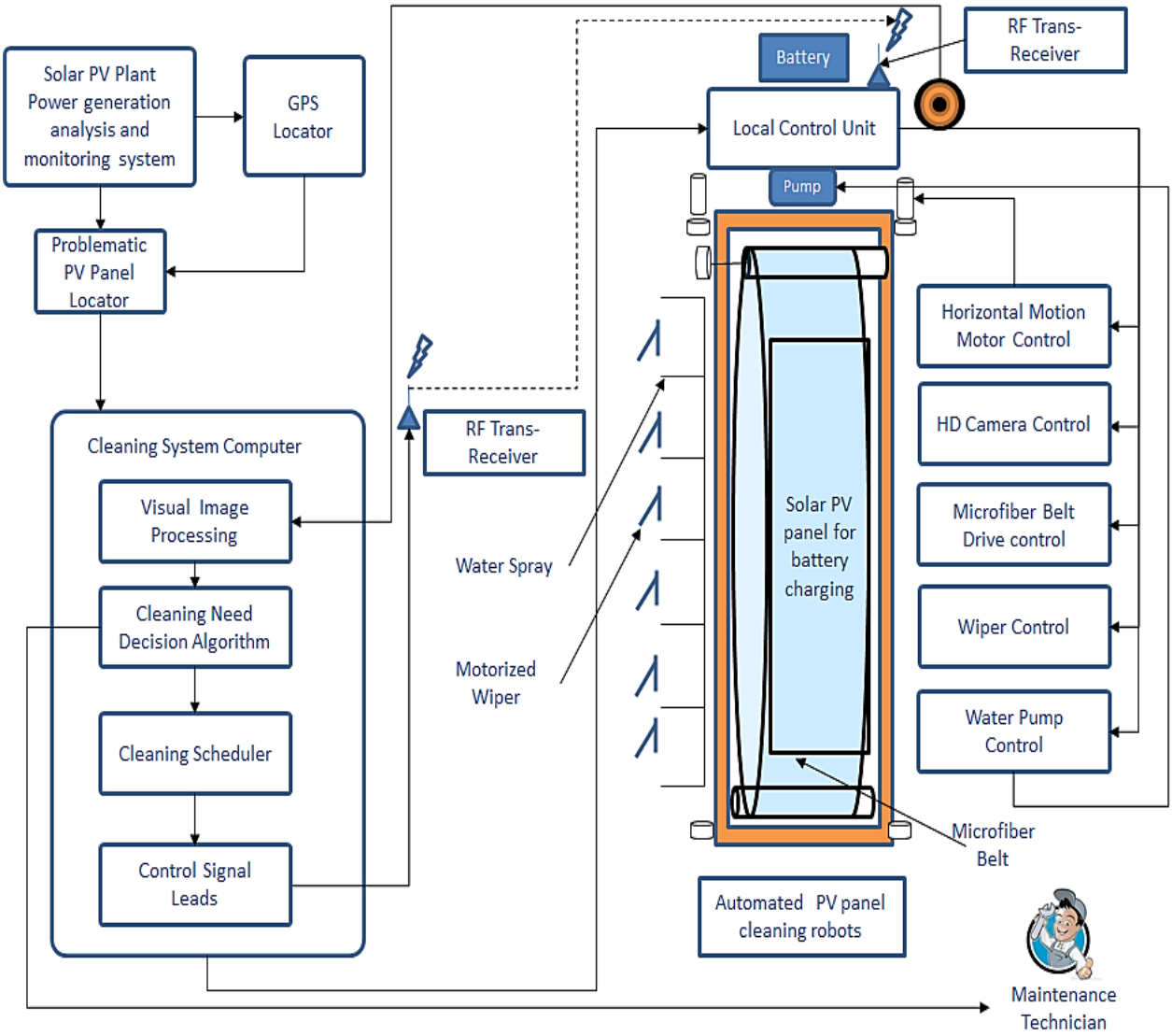


Figure 15: System Architecture

3.3. Logic Diagram

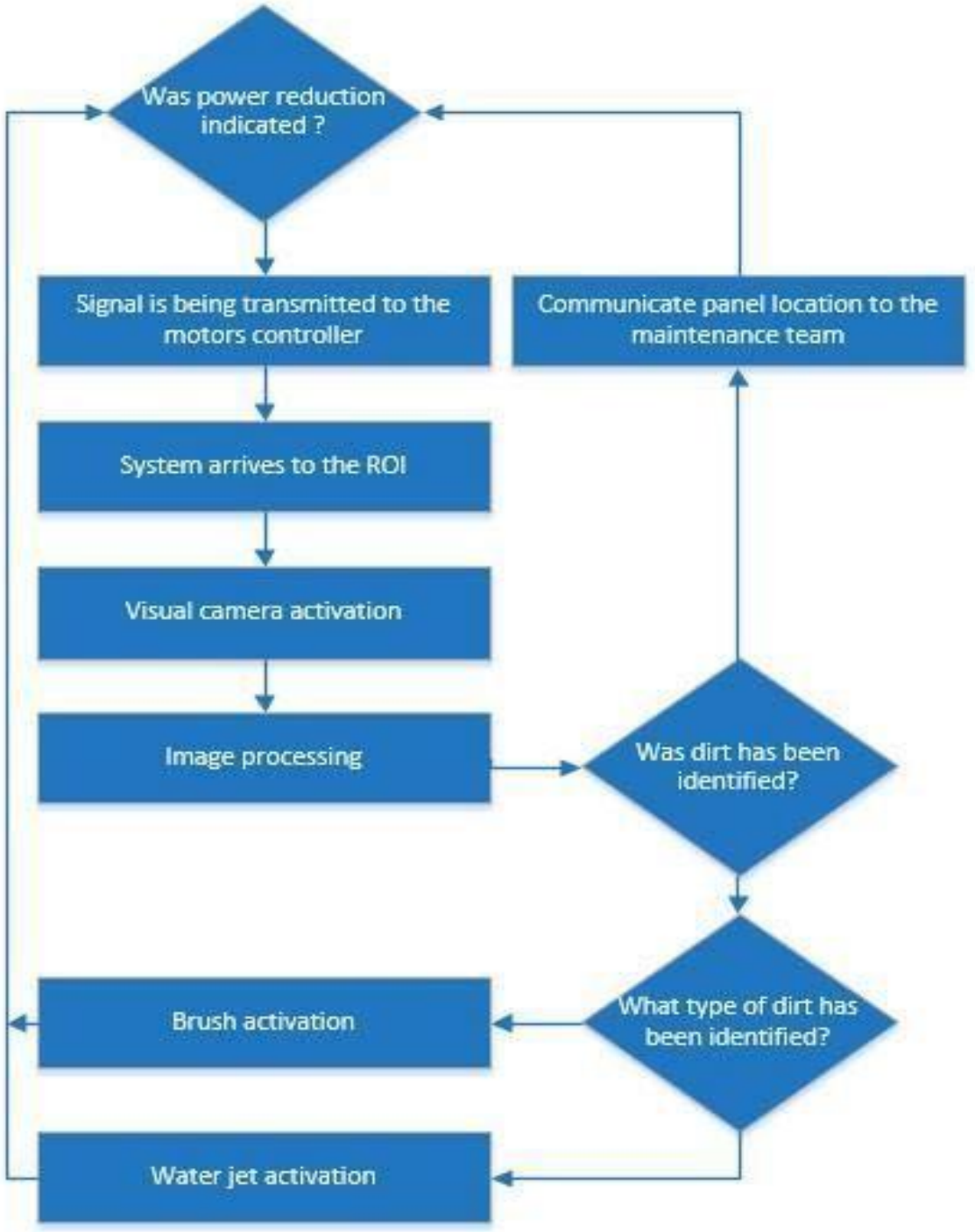


Figure 16: Logic Diagram of System

3.4. Mechanical Design

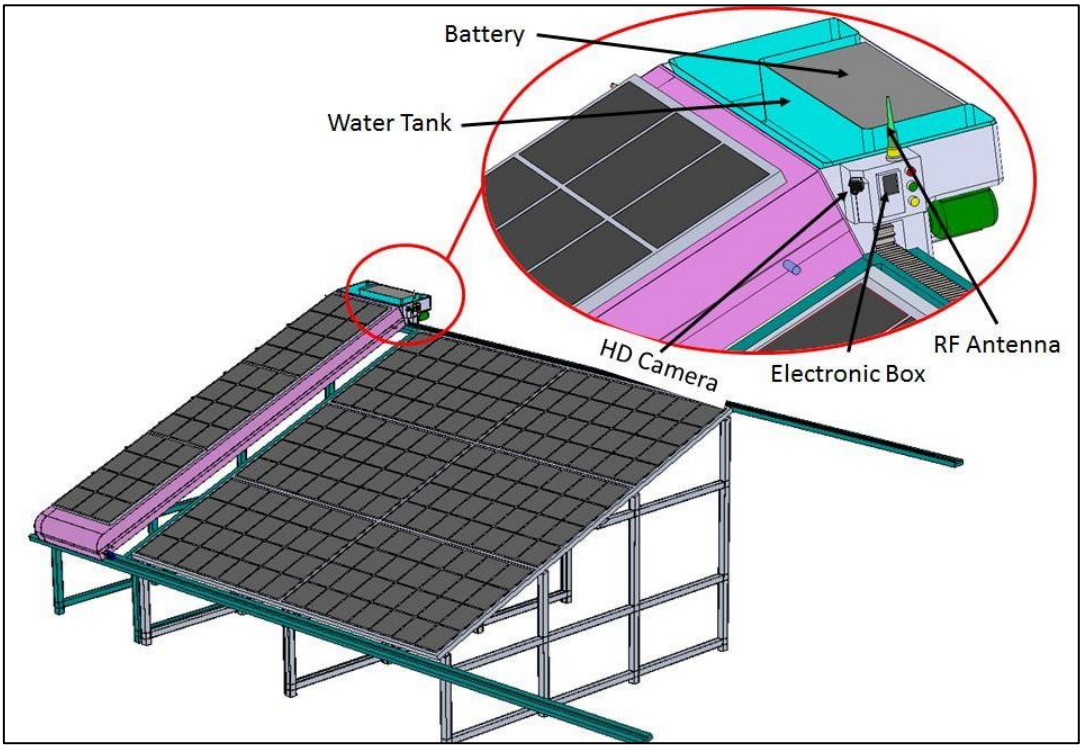


Figure 17: Detailed View of Cleaning Unit

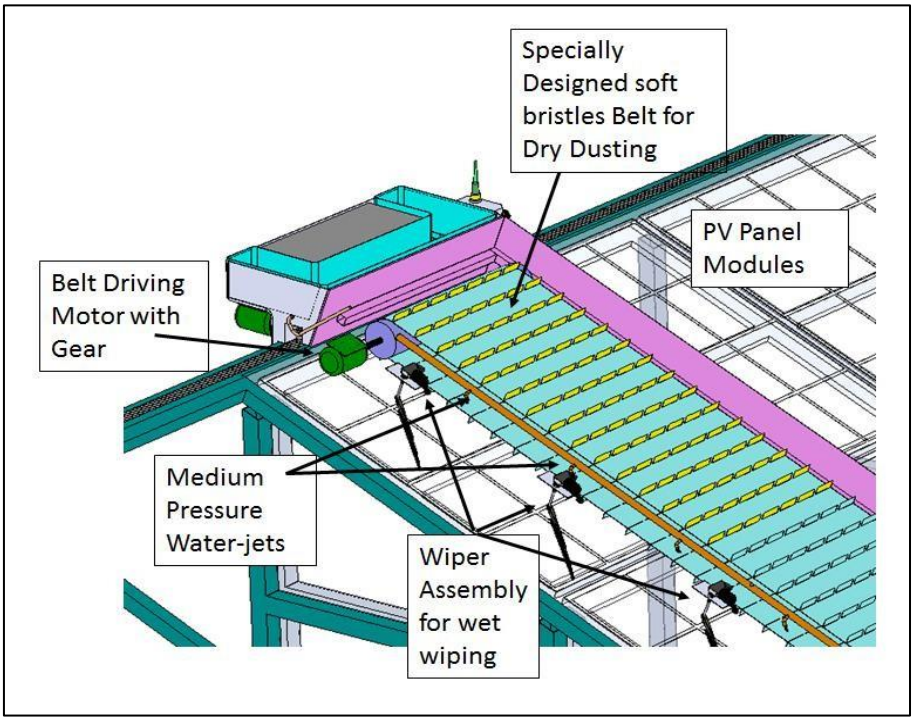


Figure 18: Cleaning Unit Internal view

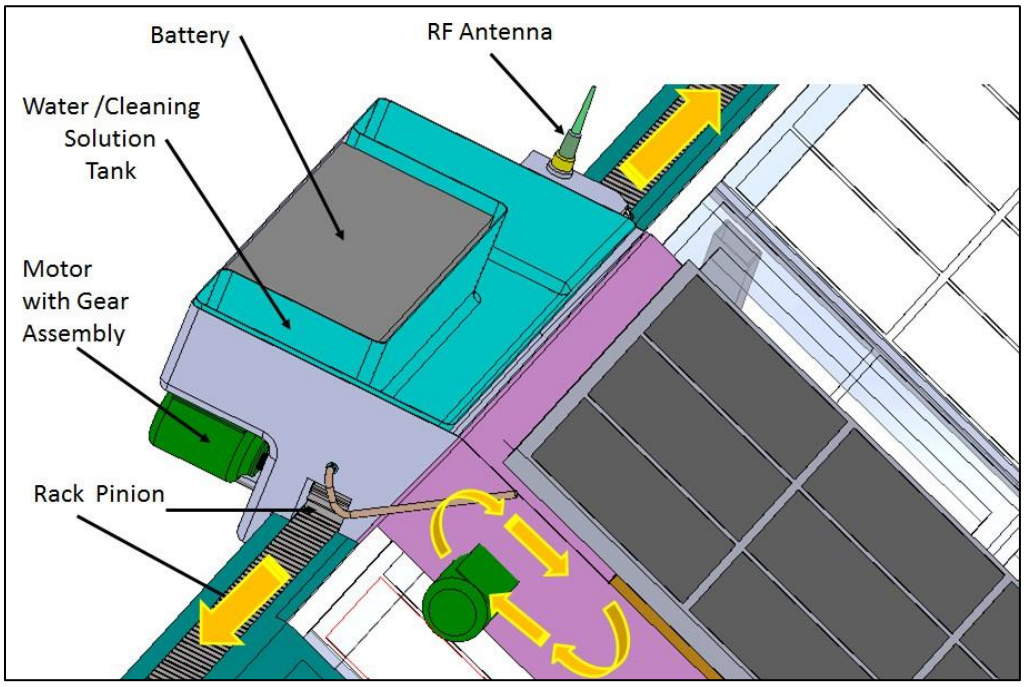


Figure 19: Cleaning Unit Carriage movement.

3.5. Electrical Design

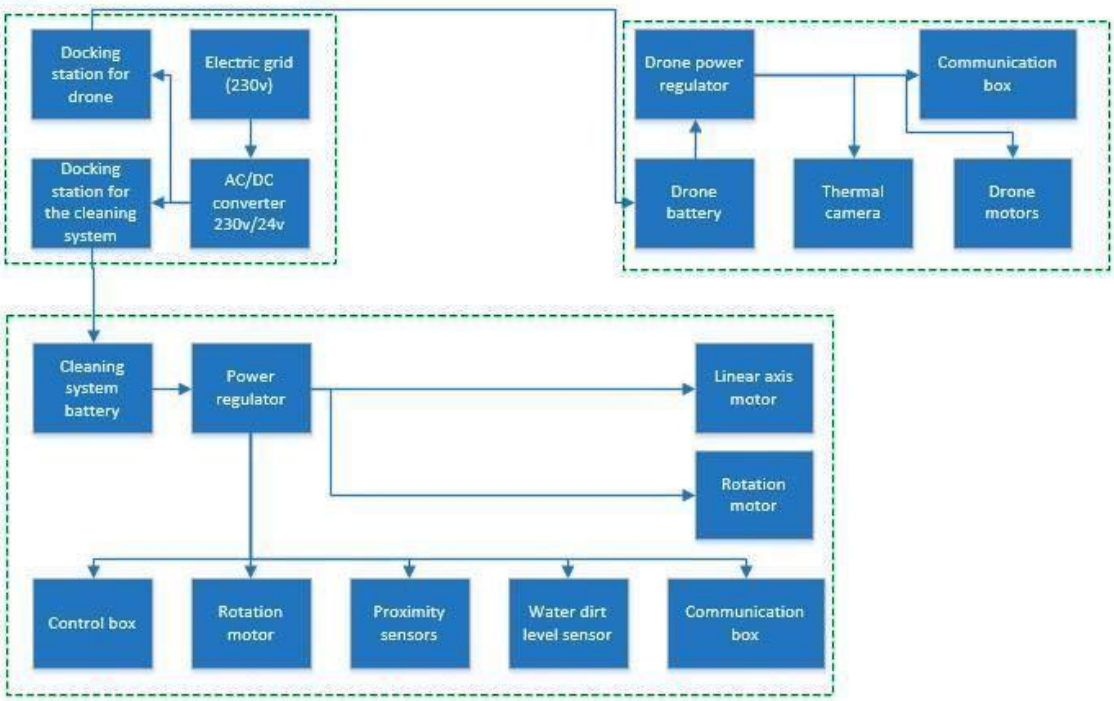
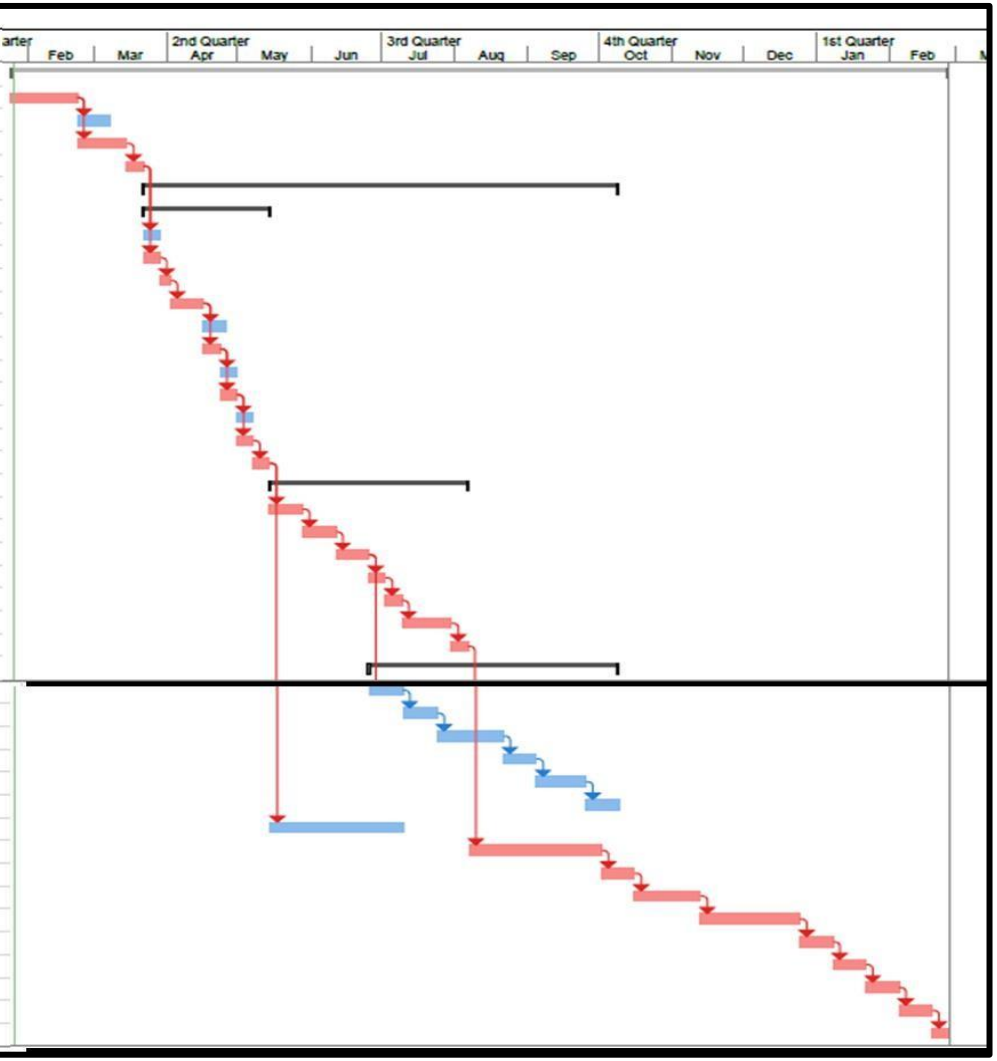


Figure 20: Electrical and Electronics Architecture

4. Project Plan

ID	Task Name	Duration
0	**Ghant Robo Knife**	**56.5 wks**
1	System high level definition and	4 wks
2	**System Requirement Review -**	**2 wks**
3	Literature Review	3 wks
4	**System Design Review - SDR**	**1 wk**
5	**Design**	**28.6 wks**
6	**Mechanical Design**	**7.5 wks**
7	Robot Docking station	1 wk
8	Mechanical Frame and rails	1 wk
9	horizontal moving platform	0.5 wks
10	cleaning carriage module	2 wks
11	cleaning sub system	1.5 wks
12	Pneomatic system	1 wk
13	water supply system	1 wk
14	motor selection	1 wk
15	wet cleaning module	1 wk
16	dry cleaning module	1 wk
17	Mechanical design CDR	1 wk
18	**Electrical Design**	**12 wks**
19	power supply system	2 wks
20	motion control system	2 wks
21	motor control system	2 wks
22	Pneomatic system	1 wk
23	water supply system	1 wk
24	communication system	3 wks
25	Electrical Design CDR	1 wk
26	**Software Design**	**15.1 wks**
27	Data interface design	2 wks
28	GUI design	2.1 wks
29	Dessiosion Algorithem	4 wks
30	software testing	2 wks
31	Data management system	3 wks
32	Software CDR	2 wks
33	LLI purchasing	8 wks
34	manufacturing and purchasing	8 wks
35	system integration and ASSY	2 wks
36	testing and certification	4 wks
37	ASSY line setup	6 wks
38	first article testing	2 wks
39	first article shipment	2 wks
40	Field installation	2 wks
41	dry run	2 wks
42	site acceptace test	1 wk



Appendix –I: Patent Grant Certificate

INTELLECTUAL PROPERTY INDIA
PATENTS | DESIGNS | TRADE MARKS
GEOGRAPHICAL INDICATIONS

सत्यमेव जयते

क्रमांक : 022113197
SL No :

भारत सरकार
GOVERNMENT OF INDIA
पेटेंट कार्यालय
THE PATENT OFFICE
पेटेंट प्रमाणपत्र
PATENT CERTIFICATE
(Rule 74 Of The Patents Rules)

पेटेंट सं. / Patent No.	:	366842
आवेदन सं. / Application No.	:	201821017882
फाइल करने की तारीख / Date of Filing	:	11/05/2018
पेटेंटी / Patentee	:	Samir Shriram Bagalkote
आविष्कारक (जहां लागू हो) / Inventor(s)	:	1.Samir Shriram Bagalkote 2.Vrushali Samir Bagalkote

प्रमाणित किया जाता है कि पेटेंटी को उपरोक्त आवेदन में यथाप्रकटित AUTOMATED SYSTEM FOR CLEANING OF SOLAR PHOTOVOLTAIC PANELS IN SOLAR ARRAY AND METHOD THEREOF नामक आविष्कार के लिए, पेटेंट अधिनियम, १९७० के उपबंधों के अनुसार आज तारीख 11th day of May 2018 से बीस वर्ष की अवधि के लिए पेटेंट अनुदत्त किया गया है।

It is hereby certified that a patent has been granted to the patentee for an invention entitled AUTOMATED SYSTEM FOR CLEANING OF SOLAR PHOTOVOLTAIC PANELS IN SOLAR ARRAY AND METHOD THEREOF as disclosed in the above mentioned application for the term of 20 years from the 11th day of May 2018 in accordance with the provisions of the Patents Act,1970.

INTELLECTUAL PROPERTY INDIA
PATENTS | DESIGNS | TRADE MARKS
GEOGRAPHICAL INDICATIONS

THE PATENT OFFICE GOVT OF INDIA

अनुदान की तारीख : 17/05/2021
Date of Grant :

पेटेंट नियंत्रक
Controller of Patent

टिप्पणी - इस पेटेंट के नवीकरण के लिए फीस, यदि इसे बनाए रखा जाना है, 11th day of May 2020 को और उसके पश्चात प्रत्येक वर्ष में उसी दिन देय होगी।

Note. - The fees for renewal of this patent, if it is to be maintained will fall / has fallen due on 11th day of May 2020 and on the same day in every year thereafter.

Appendix –II: Patent Document Copy

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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WIPO | PCT

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(74) Agent: **WANGE, Prafulla**; Bhate & Ponkshe, 12, Venumadhav, 104/7, Off Lane No. 14 Prabhat Road, Pune 411004 (IN).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,

(54) Title: AUTOMATED SYSTEM FOR CLEANING OF SOLAR PHOTOVOLTAIC PANELS IN SOLAR ARRAY AND METHOD THEREOF

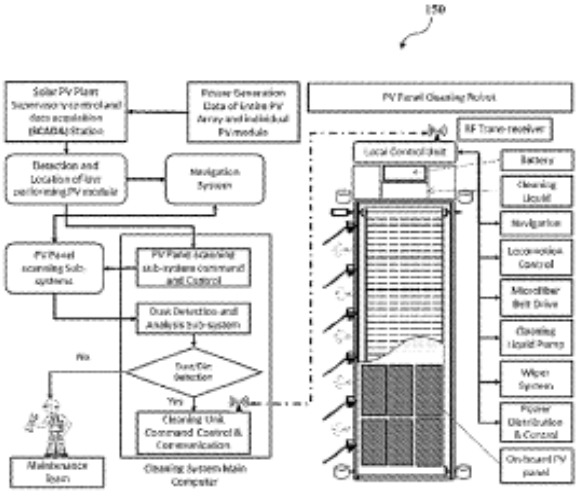


Figure 1

(57) Abstract: Disclosed is an automated system (150) for cleaning surfaces of solar photovoltaic panels in a solar array and a method (200) thereof. The system (150) consists of a robotic cleaning device (100) in communication with a supervisory control and data acquisition (SCADA) station. The device (100) comprises of a carriage frame (10), a reservoir (15), an onboard battery (20), a control unit (30), a drive assembly (35), a cleaning module (90) including a dry cleaning unit for dry dust removal and a wet cleaning unit for sticky dirt removal and a cleaning module drive unit (45). The method (200) enables to clean multiple kinds of PV installations including small rooftop set-up to large commercial scale and to remove multiple forms of dirt and dust in single cleaning device (100). The system (150) doesn't require external power feed for cleaning operations, thereby reducing power and water consumption by selective cleaning capability.

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Appendix –III: Thermal Imaging of PV Panels due accumulation



Figure 21: Dirt detection by Thermal Imaging – Hotspots detection-1

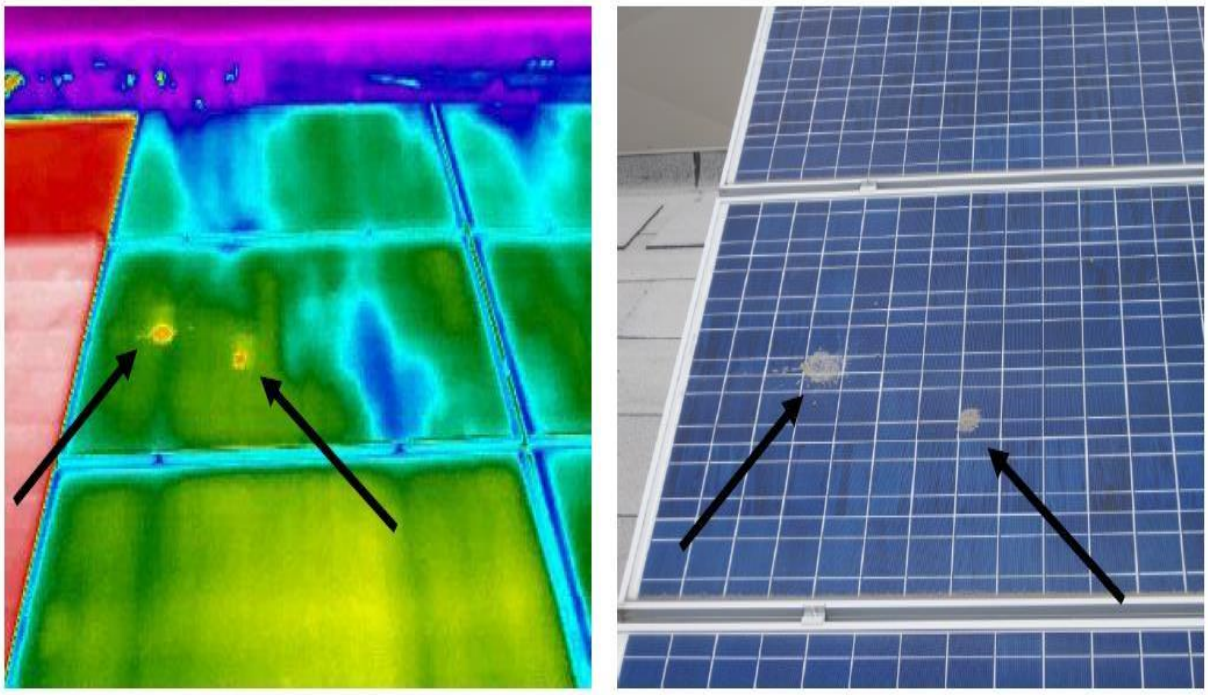


Figure 22: Bird-dropping detection by Thermal Imaging – Hotspots detection-2



Figure 23: Dust detection by Thermal Imaging – Hot-surface detection-1

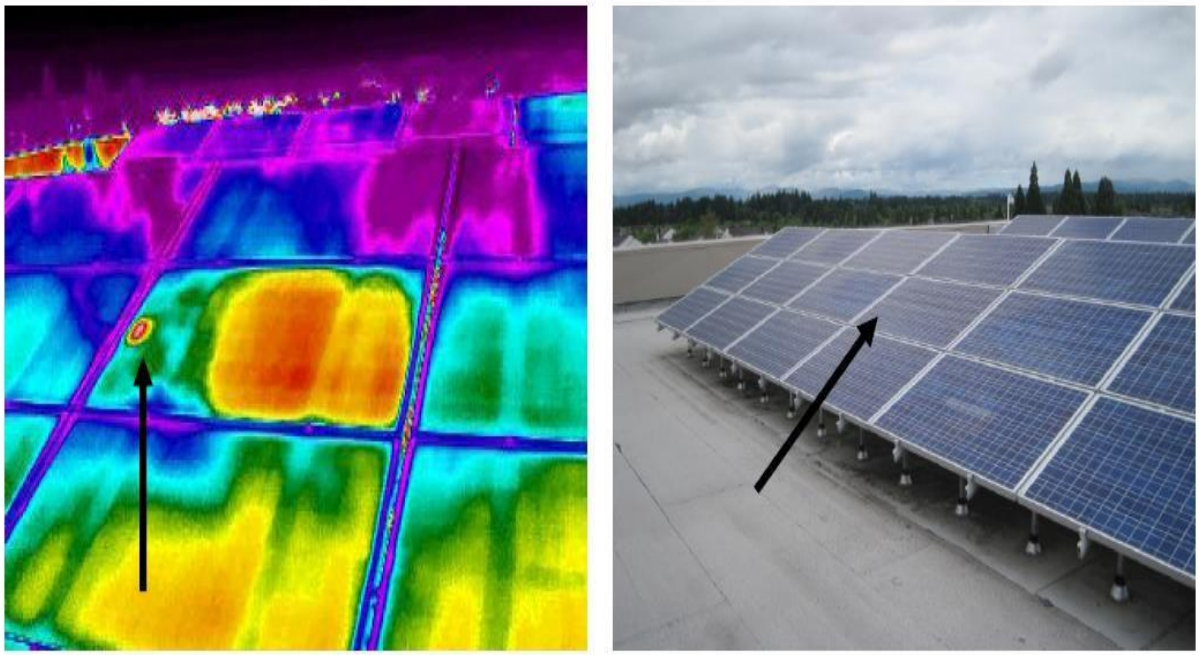


Figure 24: Dust detection by Thermal Imaging – Hot-surface detection-2

Appendix –IV: Visual Image comparison of Dirty and Clean Solar PV Panel Surface.

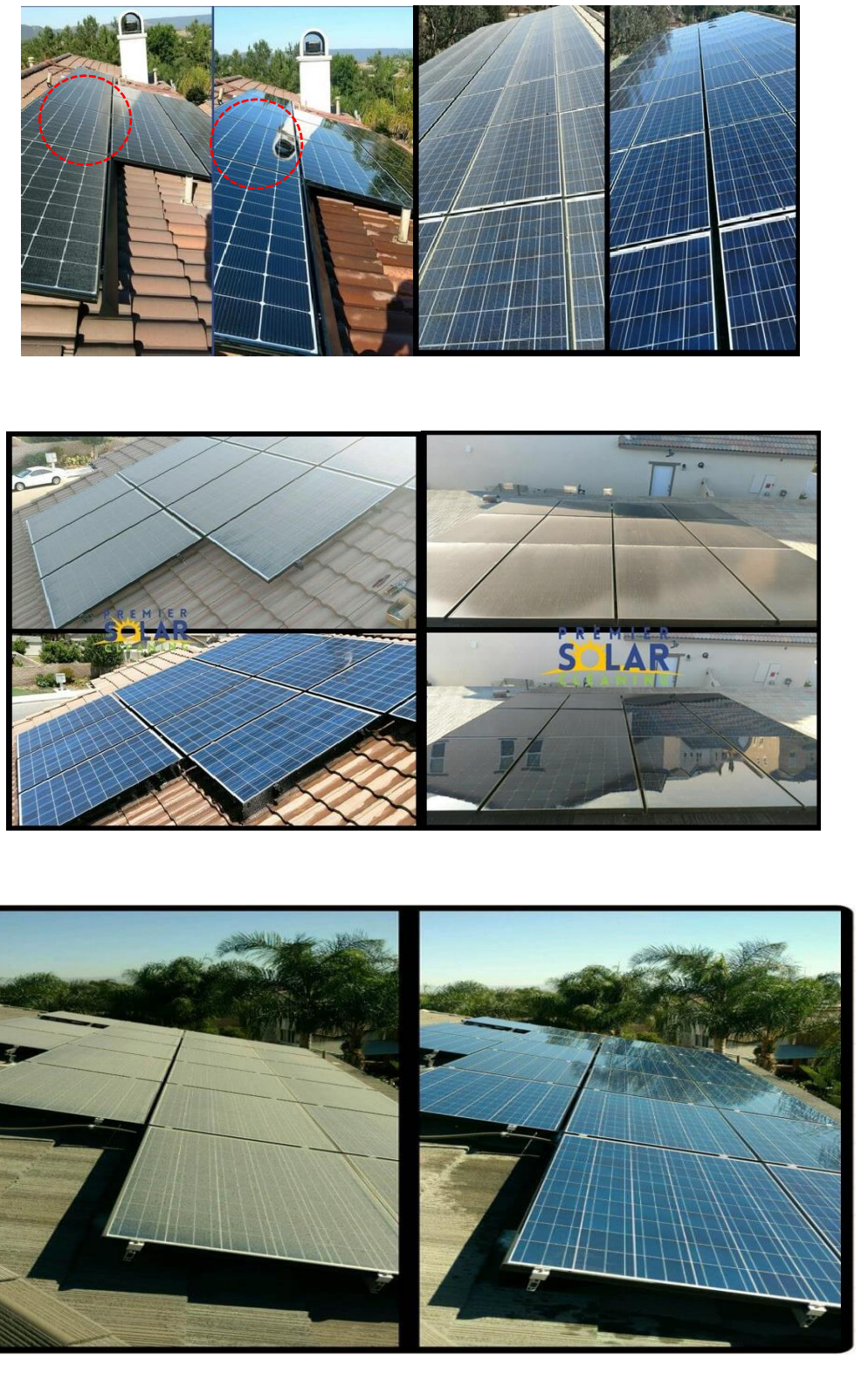


Figure 25: Visual Image comparison of dirty and clean Surface of Solar PV Panels