Examining the Economic Viability of a Solar Panel Dust Cleaning

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***Abstract*—This Solar Power has gained widespread attention by academia and government as an alternative cleaner source of energy. It is far more promising as compared to all other sources of energy. However, Solar Power has its own issues when it comes to installation. One of the major problems with solar power is dust settlement on solar panels. A number of approaches have been developed to solve this issue. However, either these approaches are very costly, inefficient or have a detrimental effect on the environment. This study systematically examines an indigenously developed Solar Panel Dust cleaning system and its impact on energy efficiency of the Solar Panel using a 1KW roof-top Solar Panel in an industrial town of India - Bhilai. The study also builds a GUI in MATLAB for prediction of energy reduction on a solar panel due to dust accumulation. Finally, this study presents a basic cost-benefit analysis to examine the return on investment in such a dust cleaning system.**

Keywords— —Solar PV system, Cleaning system, Dust accumulation, Cost-Benefit Analysis.

I. INTRODUCTION

Governments all over the world are shifting towards alternative sources of energy for fulfilling the ever-increasing energy needs of their country [1]. Solar Power is one of the supposedly cleaner sources of energy and has received a strong push in almost all the countries. With depletion of conventional energy sources, such as coal, and increasing costs of petrol and diesel, it is imperative that alternative sources of energy will be looked upon for fulfillment of the energy needs. The current installed capacity in India as of June 2018 is 23 GW and is expected to reach 100GW by 2022[1].

Although solar power is a clean source of energy, it has its own inherent challenges. Over the short-term the challenge is to provide solar power in the centralized mode to the citizens of the country as it is more amenable in the decentralized mode. Another short-term challenge is to tackle the dust settlement problem on the panel. Over the long term, the country will face problem of disposing solar cells that would be installed enmasse by then. In this paper, we focus upon the short-term problem of dust settlement on the panels. Dust settlement on solar PV panels affects the efficiency of power generation. Moreover, it reduces the life span of the solar PV panels as well as that of batteries due to improper charge and discharge phenomena [2].

Various alternatives have been considered to clean the solar panels. The simplest of all methods is to use the wiper and water to clean the panel manually. Moreover, availability of water is of concern in most areas. Natural cleaning methods using air, scour raining and gravitational force have also been used [3, 4]. Gaier et al. [3], however, argue that although natural processes are good, it is not viable to rotate the panels (either vertical or oblique) at any time of the day and during rains. And this becomes further critical with large solar panel installations. Apart from these methods, a number of mechanical methods have been developed to clean the panels. Prominent among these are electrostatic precipitator, vibrators, external blowers and ultrasonic driving [5]. Electrostatic precipitators, they suffer with poor efficiency, high energy consumption and dissatisfactory maintenance [5]. Similarly, dust removal by vibration and ultrasonic mechanism are also mechanical methods consisting of driving mechanism, frequency and the solar panel amplitude [5]. However, these being self-cleaning mechanisms are not efficient and are limited to small scale installations.

Considering several methods of dust cleaning, this study studies a solar panel dust cleaning system. The study addresses three broad aspects: (i) study of dust settlement cycle on a solar panel, (ii) Examining the economic viability of this system, and (iii) development of GUI for predicting loss in energy due to dust accumulation. This is a mechanical cleaning system using panel mounted rotatory Brush that removes the dust on the panel as it swipes through the panel. This system can be applied in all kinds of solar panel installation and is particularly suited for large installations. Thus, the objective of this study is to study various mechanisms for dust cleaning, examine the development of a mechanical dust cleaner as well as analyze its economic viability. We conducted a controlled study of the dust settlement on a solar panel and found that it influenced the efficiency of power generation from the solar panel. Since, this system is designed to clean the solar panel without water; it does not deplete other natural resource and is environment friendly as well. The rest of the paper is organized as follows. In section II, we review various dust cleaning systems and their limitations. We also review the development of a mechanical dust cleaning system developed by a start-up through entrepreneurship development cell of the institute. In section III, we present the study design and data collection methodology followed by analysis and prediction in section IV. In section V we

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present discussion and in section VI, we conclude this study with its limitations and avenues for future research.

II. LITERATURE REVIEW

Issue of Dust Settlement

Dust accumulation on solar panels is a major issue that influences its performance as well as economic viability. Maghami et al. (2015) [6], outline various factors that influence dust settlement on a panel. These are enumerated as follows:

Ambient temperature and humidity
Wind velocity
Dust properties (including dust type such as chemical, biological, electrostatic, size, shape and weight)
Glazing characteristics, such as texture of PV panel surface and its coating type.
Panel tilt angle and orientation (includes exposure movement of sun and wind)
Site characteristics such as local vegetation, pedestrian, vehicular traffic and air pollution

The problem becomes severe in highly polluted cities, industrial zones, and areas prone to sand storms. Dust storms, for example, cause severe problems mainly in arid and semi-arid regions, such as deserts. Strong winds picks up loose sand and dirt particles from the dry surface and carry them over and deposits at other places or places where its velocity is checked [7]. In India, such phenomenon is particularly common during summer seasons when the rate of dust flow is high. As solar panels are installed in places completely exposed to sun, they are prone to dust settlement. Particularly, when such panels are integrated with large buildings, they are not only tedious to clean, they take lot of time and may also prove to be hazardous for cleaners.

The problem is also acute in the industrialized cities, even if they are not prone to dust settlement. Almost all industries discharge gases which contain dust particles to varying degrees (in ppm). Even though environmental norms are in place, there is some amount of permitted discharge into the system. Such dust commonly percolates in the ambient air and gets settled when interrupted. So, unless a place received natural rainfall throughout the year, dust accumulation is a severe problem that needs to be addressed.

Another indirect impact of this dust accumulation on the solar panel is that the imbalanced generation and continuous fall in generation decreases the life span of the solar storage devices such as lead acid storage batteries. Batteries are required to store the energy generated from the solar panel. Use of batteries increase the overall maintenance cost of the solar power generation system as the charge and discharge rate of batteries varies with the intensity of sunlight during the day. Thus, depending upon the intensity of sunlight, the batteries are partially charged to fully charged. Dust accumulation reduces the intensity of sunlight and thus affect the rate of charging of battery[2,8]. Batteries are also prone to self-discharge if they are left idle for a long time due to internal electro-chemical reaction in the battery [2]. Dust accumulation also increases the overall temperature of the system and therefore, batteries need to be stored in a cool place[2,8].

Fig. 1 a. An aerial view of the dust-covered sky in Jaipur in Rajasthan on Tuesday, May 8, 2018 (Reuters)

Fig. 1 b. Visuals of dust storm hitting the Pragati Maidan area of Delhi on Monday night. (ANI)

Fig. 1 c. A dust storm was seen building up over the city of Bikaner on Monday. (PTI)

Fig. 1 d. Severe dust storm hit Rajasthan's Sikar on Monday night due to which the electricity supply was disrupted in the area. (ANI)

FIGURE 1: EFFECT OF DUST STORMS IN INDIAN CITIES

Solar Panel cleaning systems

Several methods of solar panel cleaning have emerged in the market. For example, Adani group – the largest solar power generator in India – is using the tractors with cleaning wiper or brushes and water to clean the system. However, this requires human effort as well as huge amount of water. Thus, it increases labor costs and is therefore, not economically viable. Moreover, as human beings are prone to commit errors, using human effort may create major operational issues in cleaning solar panels and it can be used only for the solar panels installed at ground. Examining each system is beyond the scope of this paper, and therefore, we look at some prominent ones, such as electrostatic

d. Severe dust storm hit Rajasthan's Sikar on Monday night due to which the electricity supply was disrupted in the area. (ANI)

precipitator and mechanical bots. Figure 2 presents a few systems developed for dust cleaning. Figure 2(a) shows Eccopia E4, which is automatic but quite expensive and takes long time for cleaning, because of its small size.Figure 2(b) shows an electrostatic system that uses electrostatic cleaning mechanism. This system is also not viable for cleaning big power plants. Figure 2(c) presents heliotex system which sprinkles water over the panel. However, it uses lots of water and useful only if availability of clean water is not a concern. Figure 2(d) shows the FWG cleaner which uses vehicle mounted cleaner to clean solar panels. It is useful only in situations where panels are placed on ground and not on rooftops or panels placed under water.

Fig. 2 a. Eccopia E4

Fig. 2 b. Electrostatic cleaning systems

Fig. 2 c. Heliotix Cleaning System

Fig. 2 d. FWG panel washer

FIGURE 2: PICTURES OF VARIOUS DUST CLEANING SYSTEMS

Electrostatic precipitator

The electrostatic precipitator is an electric method of dust mitigation from a solar panel. Clark et al [9] report that by using tribo-electric charging and photo-emission of electron from the surface by using ultra violet radiations, dust particles can be separated from a surface. The same mechanism is implemented here. The dust particles that get attracted towards the charged solar panel gets charged. As like charges repel each other, charging the panel in the opposite direction will repel the dust particles away from the panel. However, this mechanism is not economically viable for small-sized dust particles and cannot be applied for large solar plants. Moreover, this study doesn't work in case there are rains.

Mechanical bots

A number of mechanical cleaning systems have emerged in the market. In most cases, the technology used for designing them increases the cost of dust cleaning prohibitively. Some bots use water for cleaning solar panels and thus increase the concern of availability of water as well as managing water waste, thus increasing the maintenance cost of solar power plants. The system is also too costly and hence economically not viable.

Proposed Dust Cleaning System

The proposed system as shown in Figure 3 is an automatic dust cleaning system using Arduino UNO. It comprises horizontal motion of the entire system over the panel and vertical motion of a nylon brush moving vertically during the horizontal motion of the system. The system is indigenously developed by a team of entrepreneurs working on a startup under Entrepreneurship Development Cell of Shri Shankaracharya Group of Institutions, Bhilai. The dust is cleaned through the spiral motion of a nylon brush on the system. The system does not need water and draws negligible amount of electricity for its operations and as such is better than other mechanism developed for dust cleaning. This system can be used at any scale of solar power generation including roof-top solar systems, industrial, residential as well as for systems installed above water bodies. The system hardware consists of electronic circuit and its mechanical structure controlled by this electronic circuit as described briefly below.

FIGURE 3: THE PROPOSED DUST CLEANING SYSTEM

Electronic Circuit

The electronic circuit comprises L293D IC motor driver, Arduino Uno r3, Relay 24V 35A DC, DC Limit switch and a DC motor (150W, 24V) which controls the operation of the dust cleaner. Figure 4 presents a view of the electronic circuit of the system as well as relays used for triggering the voltage level.Figure 4 shows that the primary supply is given to the Arduino board Vcc1 pin which is used for controlling motor operations. Arduino needs lower voltage and is therefore supplied with an external power adaptor. It is connected to the L293D motor driver IC through pin Vcc1 that has two H bridges to provide bi-directional motion to operate either two DC motors or one stepper motor. Here, we use two DC motors, operating bidirectionally. Since, this IC has a limitation of working under current of 600 mA, it is supplied with PWM input to control the motor speed and runs at 5V logic input. The two pins – pin 16 Vcc1 and pin 8 Vcc2 supply power to the chip and DC motors respectively. The maximum power current supplied by driver outputs is drawn from pin 8 vcc2 that is connected through the power supply to the motors. Arduino supplies to the l293D IC that further controls the two DC motors. Figure 5 presents the schematic diagram of the electronic circuit.

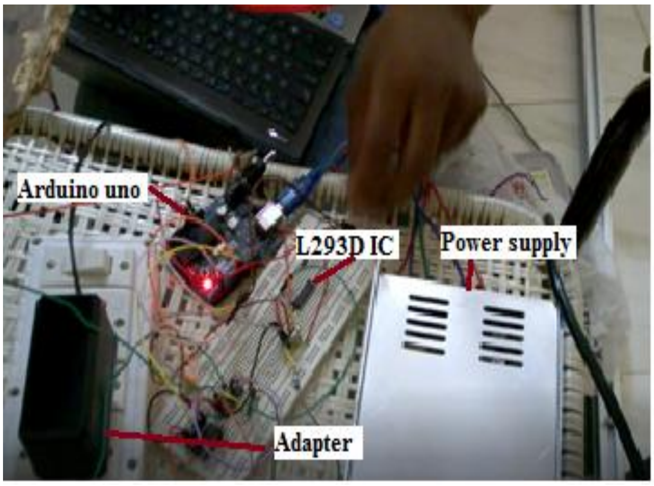

Fig. 4 a. Internal electronic circuitry

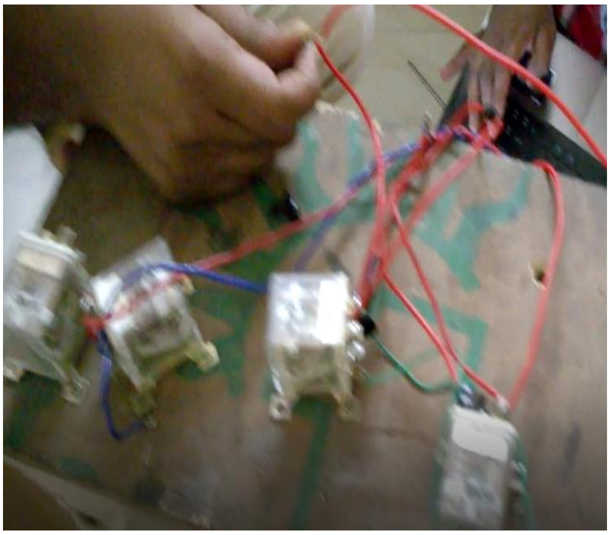

Fig. 4 b. Relays used for triggering voltage level

FIGURE 4: ELECTRONIC CIRCUIT AND CONTROL SYSTEM OF THE PROPOSED DUST CLEANING SYSTEM

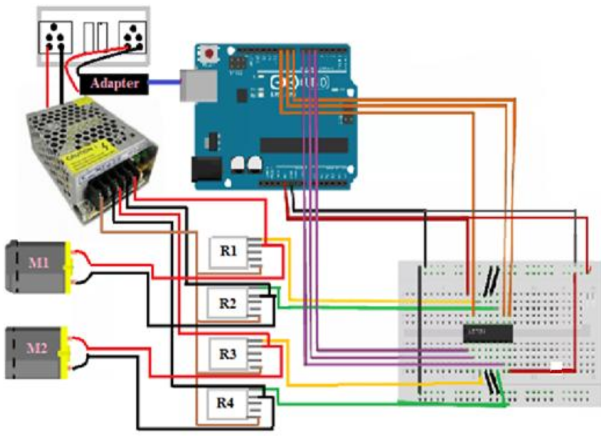

FIGURE 5: CIRCUIT DIAGRAM OF THE PROPOSED SYSTEM

Since we use higher voltage DC motors and L293D can supply only about 0.3 mA current, four relays are used to trigger the voltage level to the higher level in order to supply the motor. The motors are supplied with an external power supply rather than directly connecting to the Arduino 5V pin using switched-mode power supply (SMPS). This external power supply is made through pin 8 and ground is connected with GND Pin of the motor driver IC.This external supply is 220V AC that is brought down to lower level DC voltage with the help of Switched Mode Power Supply (SMPS) to 24 V that is used to supply the relay for triggering purpose. The four relays are connected with the direct supply that is used for triggering the voltage level from low to higher. Two relays are used for each motor. Each relay has five points, three of which are used for triggering motor operation and two are used for its own internal switching and generating the magnetic field. One of the three points is connected with positive supply of SMPS and the same pin is connected with the positive of main motor (motor used for controlling the brush rotation). The second pin is for digital signal that is provided to the IC and the third pin is GND. The second relay of the same motor controls the negative supply in order to control the clockwise and anti-clockwise operation of the brush. The second motor is used for driving the wheels for its forward and backward motion using two relays. Here, the relay is used for controlling the current flow for controlled clock wise and anti-clockwise rotation. The third pin of relay is used for signal that comes from the IC..

Mechanical Structure

The cleaning system's outward structure is made up of Nylon Bristles, cylindrical brush using spiral mechanism, Aluminum Extrusion Frame, Bearings pulley, Chain Sprocket wheel assembly, 3D printed couplers, Idler, Idler shaft, DC motor (150W, 24 V), 4 driving wheels, Brush mover, bone wheel drive, Motor 5 A, 24V, 500 rpm, Motor mount assembly, Nylon wheels, Power supply- (24V/30A) and 4-wheel drive. Figure 5 presents the outward construction of the cleaning mechanism. It has an outer frame made up of T-Shaped Aluminum Extrusion Bars because of its good mechanical properties, such as good tensile strength and robust, and good resistivity against rust. The drive motor for rotating the nylon brush is mounted at the center of the frame which is coupled with the chain sprocket assembly. The nylon brush is made up in such a way that it takes the dust from the panel and using the spiral mechanism removes the dust out through both edges of the panel. It also prevents the dust from getting again accumulated on the panel surface after once cleaned.

The second motor rotates a shaft connected with the frame parallel to the main brush Shaft as shown in Figure 6. This shaft is connected with two pullies at its edges which are coupled with other set of pullies through the chain which rotates the remaining pullies. Such connection is useful as both motors are operated using a single supply and thus provide both moving mechanism to the system as well as spiral rotation to the brush.

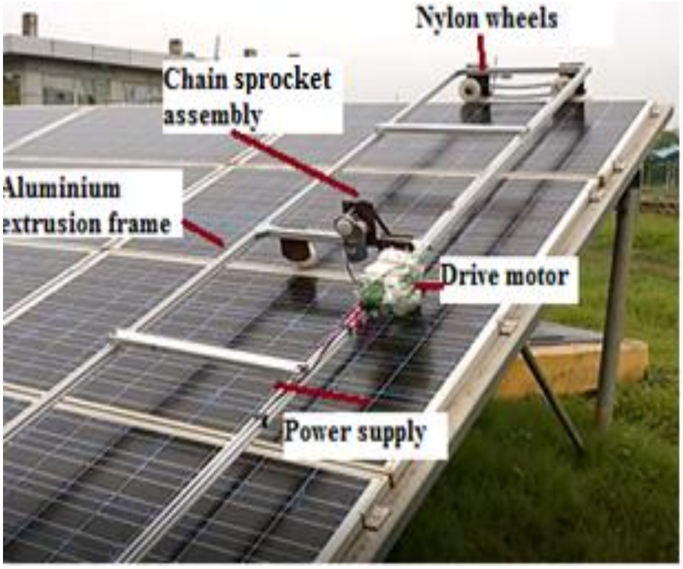

FIGURE 6: OUTWARD FRAME SHOWING ITS VARIOUS COMPONENTS

III. DATA COLLECTION METHODOLOGY AND ANALYSIS

Dust Settlement and Energy Generation

As discussed earlier, this study was conducted in two parts. In the first part, we examined the dust collection cycle and then we conducted cost-benefit analysis of the system. The data for the study was collected from a 1 KW roof-top grid-type solar PV panel installation at a house in Bhilai. Bhilai is an industrial town and host to one of the most important steel plants of India. Thus, it is very prone to dust with dust accumulation a very common occurrence in the city. The data was collected for a period of two weeks with readings taken every hour during the day from sunrise (around 7 am) to sunset (around 6 pm). Figure 7 shows the clean solar panel used for the study during the winter season and just after continuous rains for 4-5 days on 15th Februrary, 2018. Adjoining it is an inverter display unit which displays the energy generated from the solar panel.

The data was collected for two cycles, whereby each cycle was followed by cleaning of the solar panel. First cycle was during 15-20th February (6 days span), 2018 and the second cycle was during 25th February– 1st March, 2018 (6 days span), and in the second cycle. Figure 8 presents the daily energy generation for two cycles (with 12 readings for each day). We can note from Figure 8 that energy generation reduces day by day as dust accumulates in the first cycle. The panel is cleaned after first cycle and we can note that the energy generation reaches the original level and decreases again with dust accumulation in the second cycle and after cleaning the panels 3 days the per energy generation got improved as represented in table1. The test was performed within the specified conditions. Although due to the intensity of sunlight voltage value varies, the system could be a cost-effective one for cleaning the solar panels.

Fig. 7 A. A VIEW OF CLEAN PANEL JUST AFTER CONTINUOUS RAINS AT PUSHPAK NAGAR, BHILAI

Fig.7 B. INVERTER DISPLAY UNIT

FIGURE 7: A VIEW OF THE SOLAR PV PANEL FROM WHICH DATA WAS COLLECTED

It can be noted that under the specified conditions the total energy generation of the PV module goes down. The average energy reduction per day was about 4% for this particular system. Therefore, such reduction is likely to be higher for large installation. Since, the cumulative loss is high, it is important to examine the amount of energy saving that could be generated if the panel is cleaned regularly. The total reduction in energy generation during a cycle was 24%.

Figure 8 represents the two cycles of the per day energy generation. The first cycle represents the continuous reduction in the generation efficiency due to dust settlement. And the second cycle represents the degradation in efficiency and then improvement in efficiency due to cleaning.

The panels were cleaned at 27, 28,and 1 march. The data is also dependent on the sunlight intensity. And the difference is not higher because of the varying season from winter to summer where the sunlight intensity was increasing.

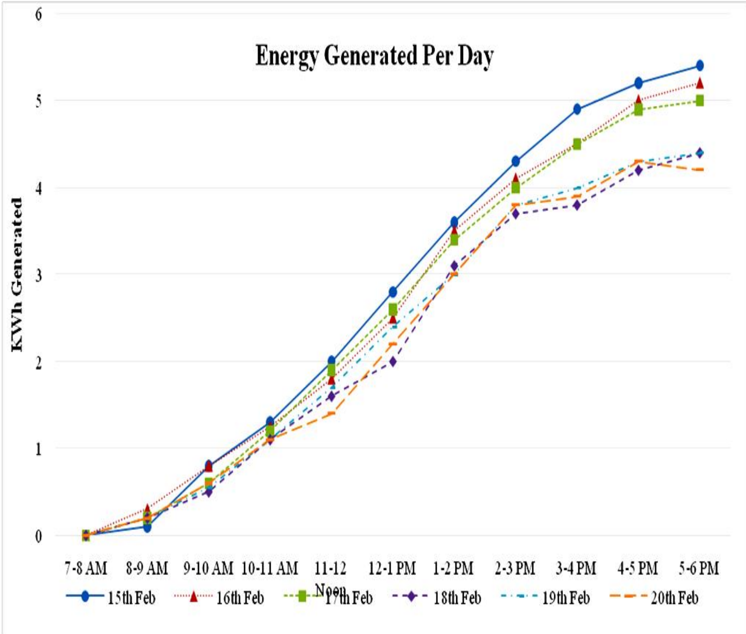

Fig. 8 a. Plot b/w generated energy v/s time interval

(First Cycle)

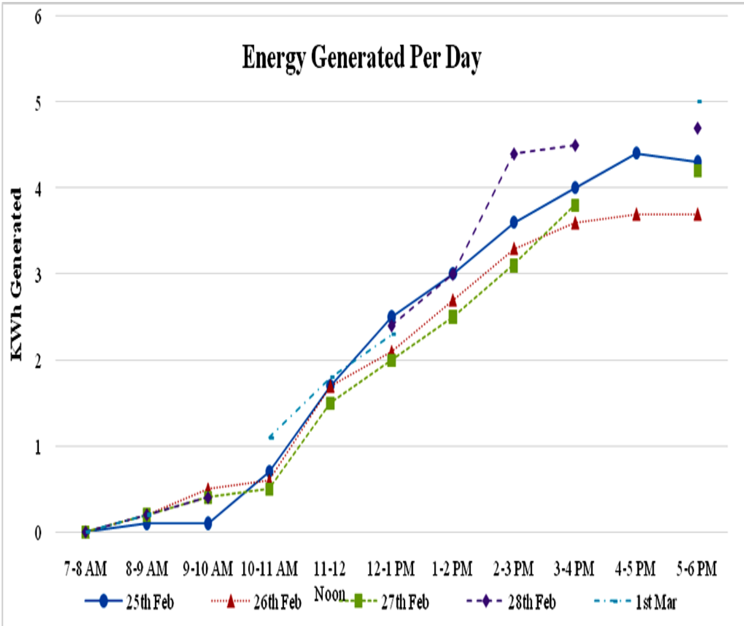

Fig. 8 b. Plot b/w generated energy v/s time interval

(Second Cycle)

FIGURE 8: THE COMPARISON OF PER DAY ENERGY GENERATION

Figure 9 presents the power generated by the panel during the day for the two cycles.

It can be noted from Figure 9 that the power generated increases during the day till noon when the sun is most intense and then gradually subsides by sunset. Figure 10 shows the PV voltage generated by the panel during the day for both study cycles.

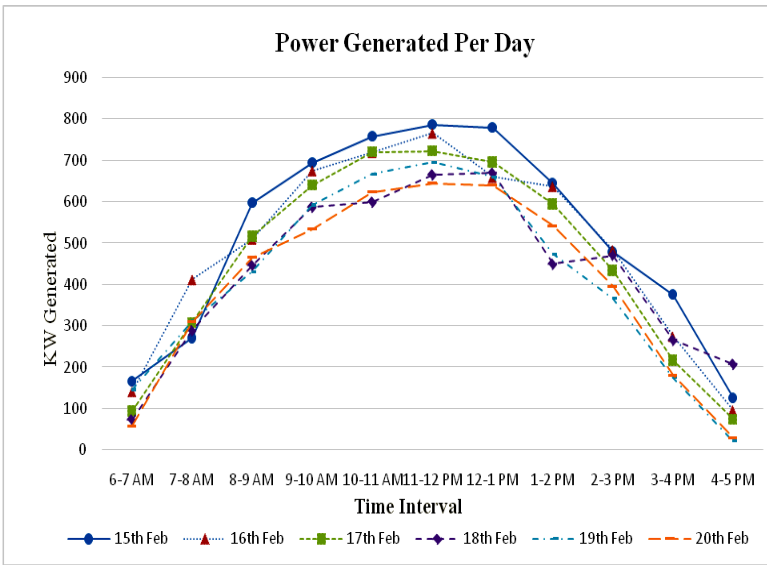

Fig. 9 a Plot b/w generated power v/s time interval (First Cycle)

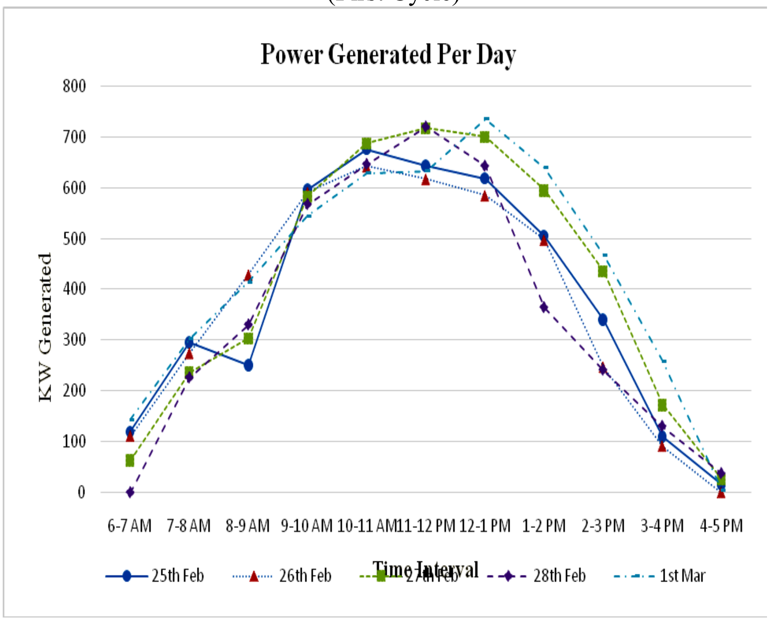

Fig. 9 b. Plot b/w generated power v/s time interval (Second Cycle)

FIGURE 9:POWER GENERATED DURING THE DAY FROM THE PANEL FOR THE STUDY DURATION

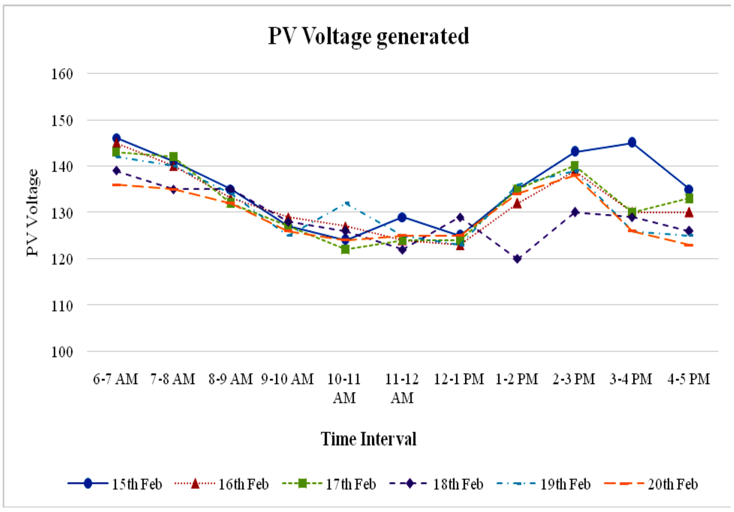

Fig. 10 a. Plot b/w PV voltage v/s time interval (First Cycle)

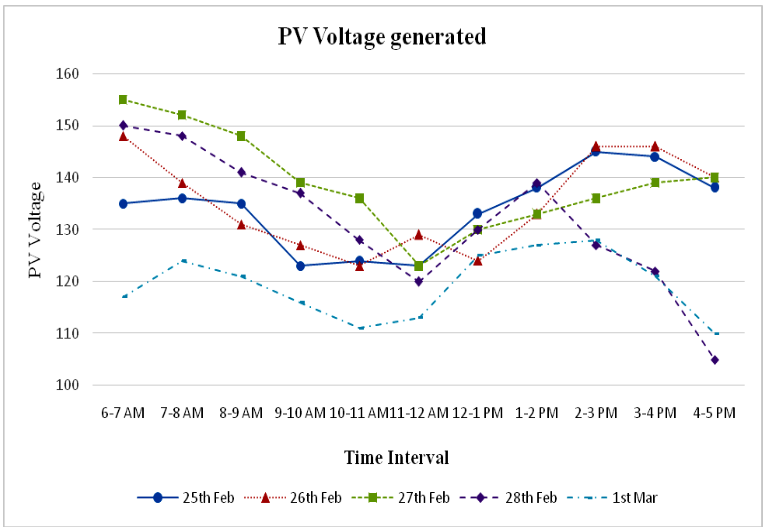

Fig. 10 b. Plot b/w PV voltage v/s time interval (Second Cycle)

FIGURE 10: PV VOLTAGE GENERATED PER DAY

We can note from Figure 10 that the daily voltage generation depends on the intensity of solar radiation. Thus, the overall calculation shows the rate of fall of generated KWh per day due to the dust deposition on the solar panel. Also, this rate will vary under various regions and climatic conditions.

Prediction of Energy Generation

Figure 11 presents a Graphical User Interface (GUI) for predicting daily reduction in power generation from the solar PV system due to dust accumulation on the panel under varying ambient conditions and in various areas where the rate of dust deposition varies according to the location and the type of locality. For example, the dust accumulation in villages is less as compared to city areas and highways or places where roads are not constructed. The GUI is developed in MATLAB 2016a.

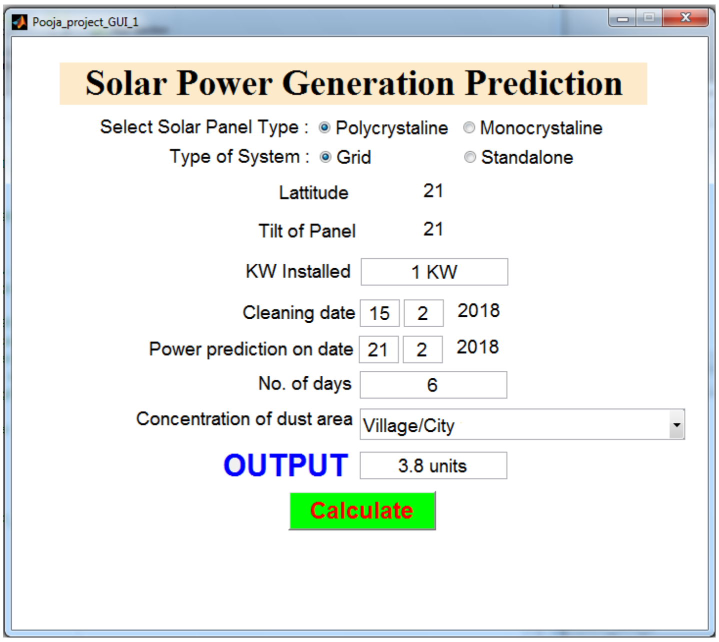

FIGURE 11: GUI FOR POWER GENERATION PREDICTION.

Table 1 shows the calculations that were used as the basis of making the GUI presented in Figure 11.

TABLE 1: CALCULATION FOR GUI

Date	Time (PM)	DailyEnergy Generated (KWh)	% change on daily basis $= \frac{x_{n-1} - x_n}{5}$
15/2/2018	5:30	5.4	0
16/2/2018	4:30	5	-8%
17/2/2018	5:10	5	0
18/2/2018	5:40	4.4	-12%
19/2/2018	5:30	4.4	0
20/2/2018	5:30	4.2	-4%
25/2/2018	5:35	4.4	+ 4%
26/2/2018	4:30	3.7	-14%
27/2/2018	5:30	4.2	+10%
28/2/2018	5:30	4.7	+10%
1/3/2018	5:45	5	+6%

Taking the average for period from 15 Feb to 21 Feb :

$$\frac{8+12+4}{20^{th} - 15^{th}} = \frac{24}{6} = 4\%\ per\ day$$

Thus, for the continuous degradation at the rate of 4% (taking time factor exception) we can predict the solar power as following considering various factors:

Factor 1 (f_1): Solar Panel Type

If we keep polycrystalline multiplication factor as 1 then monocrystalline multiplication factor can be calculated as follows:

- Polycrystalline PV panel efficiency varies from 14-17% (Average 15.5%)
- Monocrystalline PV panel efficiency varies from 20-22% (Average 21%)

Therefore, monocrystalline multiplication factor f_1= monocrystalline PV panel efficiency/ polycrystalline PV panel efficiency as:

21/15.5 = 1.355

And here for polycrystalline f_1 = 1

Factor 2 (f_2): Type of system :

Standalone system efficiency =
Solar PV → Battery → Load
75% → 60% →50%

Overall efficiency ≈50 to 60 %
Therefore, for standalone system f_2 = 0.6
Here, Grid Multiplication Factor f_2 = 1

With batteries, solar PV (DC) to Grid (AC) conversion efficiency = 80%

Factor 3 (f_3): Latitude and Panel tilt difference rate:

- The performance of the system will degrade by 4% for each 10° difference of panel tilt from the Latitude. (1-0.04x),
- x = number of days.
- The latitude and tilt angle are same for the tested system. And the difference rate would be 1.
  - Here f_3 = 1

Factor 4 (f_4): KW Installed

- It is multiplied with the output. Here the system installed was of 1 KW
  Therefore, f_4= 1.

Factor 5 (f_5): Per Day Power Generation Reduction = 4%

- Here the per day reduction rate is 4%.
- Hence, f_5 = (1- .04x)
- x = number of days.

Factor 6 (f_6):Region

- This factor decides the value of the rate of performance degradation per day. Thus, the above factor depends upon this factor. And this factor is as follows:

- City/ village = 4%, multiplication factor = (1-.04x)
- Highways = 8%, multiplication factor = (1-.08x)
- Industrial and Dirt Areas = 10 – 12%, multiplication factor = (1-.10x) or (1- .12x)
- Here f_6 = (1- .04x)

The Final output is calculated as

- Daily Power generation = 5 unit
- $5\times f_1 \times f_2 \times f_3 \times f_4 \times f_5 \times f_6$

For this test the final generation after 6 days will be

(taking x =6)

- 5×1×1×1×1× (1-.04x) ×1
- 5×1×1×1×1× (1-.04×6) × 1
- 3.8 units

Thus, the average reduction in the generated output per day is: -

The above calculation shows the reduction in panel performance due to dust for 1KW Grid system installed at Pushpak Nagar Bhilai. It could be different for village areas, unconstructed roads, highways and big cities as per the regional conditions. In case of big plants this reduction would be very high. For example, if we consider a 10KW system, then this reduction would be (1-0.24)×10 = 76%. Thus, daily reduction would be 76/6% = 12.66%/day.

Thus, we can note from the above calculation the variation in panel performance due to dust accumulation and that within 6 days, the efficiency reduction is huge. Therefore, a panel must be cleaned at regular intervals.

Using the data collected between February and March 2018, the above GUI predicts that with the daily 4% reduction in city areas. After 6 days at the 7th day the energy generated is about 3.8 units at Bhilai. owing to dust without considering any other factor.

Cost-Benefit Analysis

Here, we present a basic cost-benefit analysis of the proposed system. Any cost consists of fixed as well as variable cost. The fixed cost of the system would include primarily its purchase and installation cost. The variable cost will include the cost of operation of the system.

- Fixed cost: Rs. 14000/- (The actual cost including R&D was 45,000/-. However, commercial cost would be much lower as R&D cost would be spread over large number of units).
- Variable Cost: Considering it negligible as the operation cost is very low
- Cost savings (considering that the panel is cleaned manually every month):

  1. Unit generated per day = 5 KWh

  2. Units generated for 30 days under full efficiency = 150 KWh

  3. Reduction in units generated due to dust @ 4% per day for a month is as:

  $$150- 150*(1-0.04)^{30} = 106\text{KWh}$$

  4. Cost saving @Rs. 4/- per unit for a month is Rs. 424/-

  5. Return on Investment

  14000/424 = 33 months = 2.75 Years.

V. DISCUSSION

The automatic solar panel dust cleaning system is a cost-effective technique for the maintenance of the solar power plants and the investment on the same could be recovered in 3 years. Table 3 presents a comparison of the controlled brush cleaning system with other techniques of PV dust cleaning.

TABLE 3: COMPARISON OF VARIOUS TECHNIQUES OF PV DUST CLEANING

Methods	Manual Cost	Water	Equipment Cost	Environment Requirement	Cleaning Efficiency
Manual Cleaning	Extremely High	Low	Low	Low	Very Low
High Pressure Water Jet	High	Extremely High	High	High	Good
Professional Equipment	High	Low	Very High	Very High	Good
Controlled brush cleaning	None	None	Medium	Low	High

From Table 3, we can note that the proposed Solar Panel dust cleaning system is an economically viable system as well as environmentally responsible. It would be more economical than hiring a manual labor for cleaning a panel which would cost more than 1 Lakh /year. The controlled brush cleaning system is a one-time installation and eliminates this cost. Thus, the proposed system is quite cost-effective.

VI. CONCLUSION, LIMITATIONS AND FUTURE RESEARCH

Thus, based on this study, we can conclude that controlled brush system is simple and cost-effective solution for tackling dust settlement issue on the solar panels. This study contributes by presenting a study on the effect of dust on the energy generation efficiency of solar panels. The study also develops a GUI for predicting reduction in energy generation at a specific location. This study would be useful for examining efficiency of Solar Panel and consequent policy development. The results of this study should be examined in the light of its limitations. First, this study was done on a small panel. The behavior on a large panel needs to be studied in greater detailas the impact of dust settlement on a large panel might be different than on a small panel and the economics of dust cleaning would be different. It would save a lot of energy loss due to dust settlement as well as enhance the efficiency of the solar power plant. Secondly, the system could be further made on the IOT platform by providing Web access for automatic switching of the system.

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