Self-Cleaning Solar Panel System

Can a self-cleaning solar panel system be created which can detect and clean the dust to increase the efficiency of the solar panel on Earth and Mars?

Abstract

Solar Power will lead the way in the transformation of the global electricity sector by becoming the second prominent source by 2050 on Earth. (IRENA) One of the best places to put a solar panel is in the desert, where it is sunny. But deserts are also dusty, which means the panels have to be cleaned frequently so the dust does not stop them from capturing sunlight. "This is a serious problem that contributes to reduction of the solar cells efficiency by 40%" states Levitan. **NASA declared its Opportunity Mars rover dead after the solar-powered robot went silent during a raging dust storm on the Red Planet. Dust is a common quandary that decreases the efficiency of solar panels.**

One possible way to increase solar panel efficiency is through a self-cleaning solar panel wiper system. The design consists of a motor, a dust sensor, an arduino board, and a self-created rubber wiper to clean the solar panel. The dust sensor detects the amount of dust in the environment using the arduino board, and activates the motor which moves the rubber wiper when dust accumulates on the solar panel. The solution cleans and increases the efficiency of the solar panel.

The solar panel saw a power loss of 74% when dust accumulated on it. After using the Self Cleaning Solar Panel solution, it was able to regain the power back up to 93% of the original power generated.

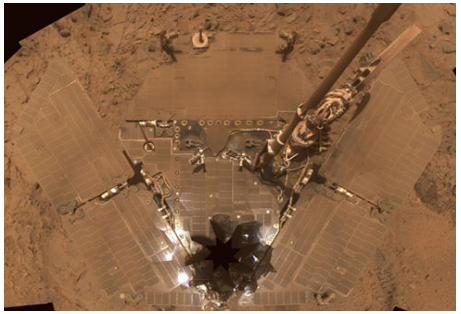
This solution has been tested at ASU Solar Power Photovoltaic Reliability Labs on the larger solar panels. The self-cleaning solar panel solution is designed for use on Earth and Mars. It does not require humans or water. On Mars, this solution can protect the solar powered rovers from the raging dust storms. As stated in the research, on Earth by 2050 solar energy will become the second most prominent source of electricity. **The self-cleaning solar panel solution self detects and self cleans the dust, is inexpensive, and can be installed all over the world to increase the efficiency of the solar panel.**

Engineering Need

NASA declared its Opportunity Mars rover dead after the solar-powered robot went silent during a raging dust storm on the Red Planet. Dust is a common quandary that decreases the efficiency of solar panels, crippling rovers on Mars.

The production of electricity using traditional energy sources is the main cause for industrial pollution on Earth. This has led to the search of alternative energy sources, such as Solar Power. **Solar Power will lead the way in the transformation of the global electricity sector by becoming the second prominent source by 2050 on Earth.**

One of the best places to put a solar panel is in the desert, where it is sunny. But deserts are also dusty, which means the panels have to be cleaned frequently so the dust does not stop them from capturing sunlight. **"This is a serious problem that contributes to reduction of the solar cells efficiency by 40%"** states Levitan.



Source: NASA

Source: Research Gate

There is a need for a system that can self-detect and self-clean the dust to increase the efficiency of the solar panels on Mars and Earth.

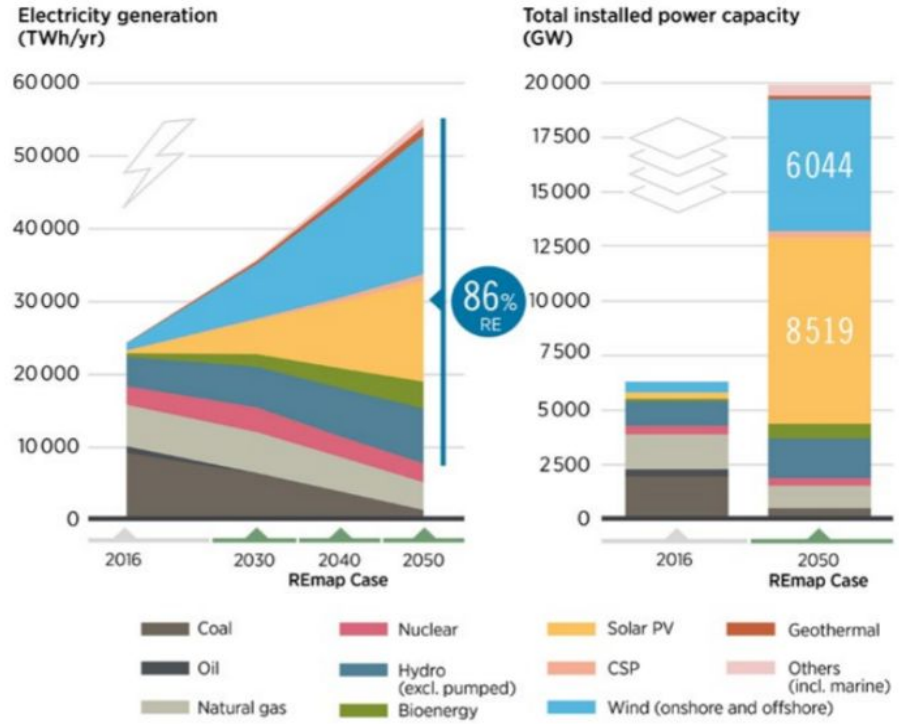
Research

Solar PV power will supply 25% of total electricity demand. The global installed capacity of solar PV would rise six-fold by 2030 (2840 GW) and reach 8519 GW by 2050 compared to installations in 2018 (480 GW). (IRENA).

In desert area, the accumulation of dust on PV panel surface is very high. Dust deposition in Arizona is about 17 grams per square meter per month, and the efficiency decreases 40% with only 1 seventh of an ounce of dust per square yard. (Malay Mazumder).

"Cleaning can cost up to five dollars per panel," says Seamus Curran, "That might not sound like a lot of money, but if you have 52,000 panels it adds up quickly."

Figure 3: Solar PV would have the largest installed capacity expansion by 2050



Notes: CSP = concentrating solar power; TWh = terawatt hour.

Source: IRENA (2019a).

Self-cleaning solar panel description

Solar panel efficiency refers to how much of the incoming energy is converted into electrical power. It is dependent on clean photovoltaic panels. Dust is a common hindrance to the efficiency of solar panel.

One possible way to increase solar panel efficiency is through a self-cleaning solar panel wiper system. The design consists of a motor, a dust sensor, an arduino board, and a self-developed rubber wiper to clean the solar panel. The dust sensor detects the amount of dust in the environment using the arduino board, and activates the motor which moves the rubber wiper when dust accumulates on the solar panel. The solution cleans and increases the efficiency of the solar panel.

The first prototype used pipe cleaners to sweep the dust off; however, the dust accumulated on the pipe cleaners and made the solar panel even more dirty. The second prototype used the rubber wipers to effectively clean the solar panel. This solution could be a potential invention as advised by Dr. Mani from the ASU Photovoltaic Reliability Lab.

Current Options in the Market

Solution	Description	Advantages	Disadvantages	Dust Detection
Manual Cleaning using mop or Vacuum Cleaners	A human operator cleans the panels with a mop or vacuum usually climbing the solar panels and the quality of the cleaned surface is judged by visual method.		-Chances of physical damage to the solar panel -safety of the person -time required to clean -does not work on Mars	Only cleaned when operator is scheduled to clean
Solar Sharc	Solar Sharc is a transparent non-stick coating which aims to prevent the accumulation of dust and debris thus optimising efficiency.	-One time installment	-dust settled on solar panel will be blown away by wind or carried away by water	No
Electro dynamic Screen	The EDS film generates a traveling electric field that charges and sweeps the dust particles from the module surface.	-no physical contact -automatically detects dust	-cost is very high	Yes
Self-cleaning Solar Panel	The dust sensor detects the amount of dust in the environment using the arduino board, and activates the motor which moves the rubber wiper when dust accumulates on the solar panel. The solution cleans and increases the efficiency of the solar panel.	-no physical contact -automatically detects dust -inexpensive -powered by solar panel -works on Mars and Earth		Yes

Design Requirements, Constraints and Materials

Design Requirements

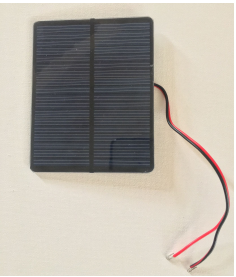
- Automatic dust detection using arduino dust sensor
- Activates self-cleaning wiper mechanism to sweep the dust
- Wiper mechanism powered by solar panel
- Improves overall solar panel efficiency

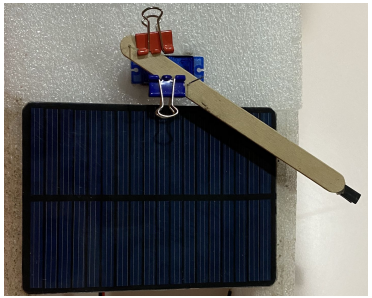
Constraints (Usable on Mars)

- No water used for cleaning
- No human requirement
- Lightweight

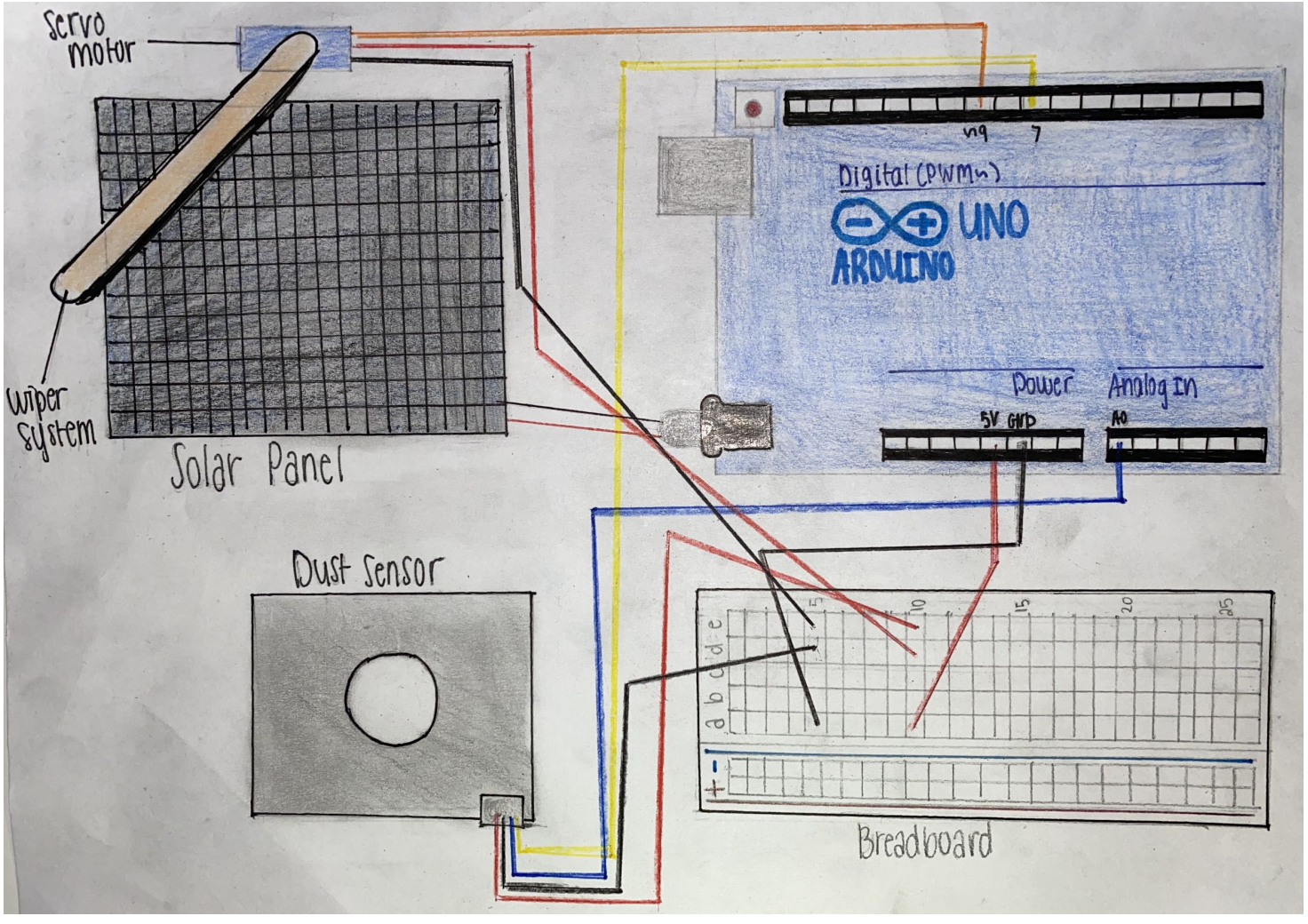
Materials

- 2 5V solar panels
- 1 arduino board
- 1 dust sensor
- 1 breadboard
- 1 Multimeter
- 1 motor
- 1 popsicle stick
- 1 windshield wiper
- 2 binder clips
- 2 needles
- 20 wires
- Styrofoam





Initial Design



CODE

```
#include <Servo.h>
// create servo object to control a servo
Servo myservo;
// variable to store the servo position
int pos = 0;

// Arduino pin numbers.
// Arduino digital pin 7 connect to sensor LED.
const int sharpLEDPin = 7;
// Arduino analog pin 5 connect to sensor Vo.
const int sharpVoPin = A0;

// Set the typical output voltage in Volts when there is zero dust.
static float Voc = 0.6;

// Use the typical sensitivity in units of V per 100ug/m3.
const float K = 0.5;

// Arduino setup function.
void setup() {
  // attaches the servo on pin 9 to the servo object
  myservo.attach(9);
  // Set LED pin for output.
  pinMode(sharpLEDPin, OUTPUT);
  // Start the hardware serial port for the serial monitor.
  Serial.begin(9600);
  // Wait two seconds for startup.
  delay(2000);
  }

// Arduino main loop.
void loop() {
  // Turn on the dust sensor LED by setting digital pin LOW.
  digitalWrite(sharpLEDPin, LOW);
  // Wait 0.28ms before taking a reading of the output voltage as per spec.
  delayMicroseconds(280);
  // Record the output voltage. This operation takes around 100 microseconds.
  int VoRaw = analogRead(sharpVoPin);
  // Turn the dust sensor LED off by setting digital pin HIGH.
  digitalWrite(sharpLEDPin, HIGH);
  // Wait for remainder of the 10ms cycle = 10000 - 280 - 100 microseconds.
  delayMicroseconds(9620);
  float Vo = VoRaw;

  // Compute the output voltage in Volts.
  Vo = Vo / 1024.0 * 5.0;
  printFValue("Vo", Vo*1000.0, "mV");
   // Convert to Dust Density in units of ug/m3.
  float dV = Vo - Voc;
  if ( dV < 0 ) {
    dV = 0;
    Voc = Vo;
  }
   float dustDensity = dV / K * 100.0;
  printFValue("DustDensity", dustDensity, "ug/m3", true);
  if ( dustDensity > 10 ) {
    for (pos = 0; pos <= 180; pos += 1) { // goes from 0 degrees to 180 degrees
    // in steps of 1 degree
    myservo.write(pos); // tell servo to go to position in variable 'pos'
    delay(5);           // waits 15ms for the servo to reach the position
  } } } // END PROGRAM
```

Build Procedures

A. **Build the solar panel wiper**

1. Poke two holes on the popsicle stick proportional to the holes on the motor.
2. Place the needles in the holes so they are fitting through the popsicle stick and the motor.
3. Secure with binder clips.
4. Next, take the rubber from car wiper and trim it to the size of the popsicle stick.
5. Glue the rubber on the bottom of the popsicle stick.

B. **Build the circuit**

1. On the servo motor, connect the black wire (GND) onto A10 on the breadboard.
2. Connect the red wire (5V) onto D5 on the breadboard.
3. Connect the Orange wire (signal) onto Digital AI 9 on the arduino.
4. Take the dust sensor, connect the red wire (5V) onto E5 on the breadboard.
5. Connect the black wire (GND) onto d10 on the breadboard.
6. Connect the blue wire (analog output) into Analog IN 0 on the arduino.
7. Connect the yellow wire (module drving pin) onto Digital AI 7 on the arduino.

C. **Put the solution together**

1. Place the two solar panels next to each other on one end of the styrofoam.
2. Tape the solar panels to the styrofoam on the back.
3. On the other end, cut a hole and put the motor in the hole.
4. Place the dust sensor next to it on top of the solar panel.

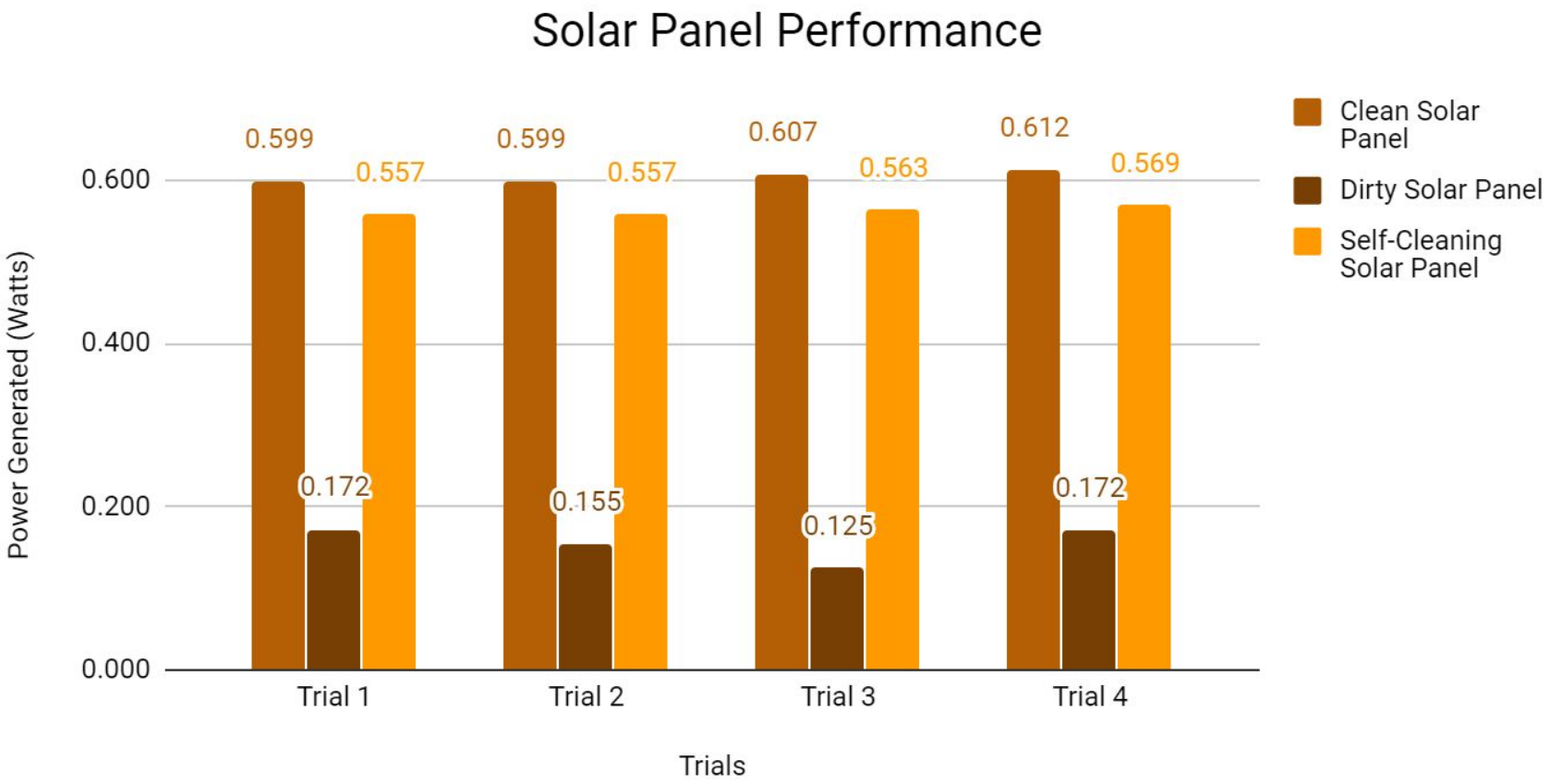
Test Procedures

1. Place the solar panels at a 33 degree angle facing the sun.
2. Place the dust sensor next to the solar panel at the same angle.
3. Blow dust onto the solar panel and dust sensor.
4. Using the multimeter, measure the voltage and current of the clean and dirty solar panels.
5. Record the voltage and current of the solar panels.
6. After a couple of seconds, the self-cleaning solar panel system will activate.
7. Record the voltage and current of the clean solar panel.
8. Repeat steps 1-7 for 3 more trials.

Data Table

Trial	Time	Status of solar panel	Voltage (Volts)	Current (Amps)	Power (Watts) = Volts*Amps
Trial 1	2:48	Clean Solar Panel	9.98	0.06	0.5988
	2:51	Dirty Solar Panel	5.74	0.03	0.1722
	2:55	Self-Cleaning Solar Panel	9.95	0.056	0.5572
Trial 2	3:05	Clean Solar Panel	9.98	0.06	0.5988
	3:08	Dirty Solar Panel	5.15	0.03	0.1545
	3:12	Self-Cleaning Solar Panel	9.95	0.056	0.5572
Trial 3	3:18	Clean Solar Panel	10.12	0.06	0.6072
	3:20	Dirty Solar Panel	4.16	0.03	0.1248
	3:26	Self-Cleaning Solar Panel	10.05	0.056	0.5628
Trial 4	3:32	Clean Solar Panel	10.2	0.06	0.612
	3:35	Dirty Solar Panel	5.72	0.03	0.1716
	3:40	Self-Cleaning Solar Panel	10.16	0.056	0.569

Graph


Solar Panel Performance
Power Generated (Watts)
0.600
0.400
0.200
0.000
0.599
0.557
0.172
0.599
0.557
0.155
0.607
0.563
0.125
0.612
0.569
0.172
Trial 1
Trial 2
Trial 3
Trial 4
Trials
Clean Solar Panel
Dirty Solar Panel
Self-Cleaning Solar Panel

Mathematical analysis of data

Percentage Decrease in Power When Dust Accumulates onto the Clean Solar Panel	Percentage Decrease in Power from clean solar panel to self cleaning solar panel
Percent decrease in Power (Watts) = (W1 - W2) / W1 x 100 = {[(.5988-.1545)/ .5988] x 100} = 74% decrease in Power	Percent decrease in Power (Watts) = (W1 - W2) / W1 x 100 = {[(.5988-.5572)/ .5988] x 100} = 6.9% decrease in Power

Looking at the mathematical data analysis presented, when dust accumulated on the clean solar panel, the solar panel saw a 74% loss in power, 52% loss in voltage, and 50% loss in current. After using the solution, the solar panel saw a 6.9% loss in power, 1% loss of voltage, and a 6.7% loss in current.

Conclusion

The data showed these 3 main points: dust is a hindrance to efficiency of solar panel, the self cleaning solar panel system cleaned the dust and the system increases the efficiency of the solar panel.

The solar panel saw a power loss of 74% when dust accumulated on it. After using the Self Cleaning Solar Panel solution, it was able to regain the power back up to 93% of the original power generated.

This solution has been tested at ASU Solar Power Photovoltaic Reliability Labs and on larger solar panels. The self-cleaning solar panel solution is designed for use on Mars and Earth. It does not require humans or water. On Mars, this solution can protect the solar powered rovers from the raging dust storms. On Earth as stated in the research, by 2050 solar energy will become the second most prominent source of electricity. So, this solution will increase the amount of electricity generated by the solar panel.

The self-cleaning solar panel is a complete solution which self detects and self cleans the dust, is inexpensive, and can be installed on Mars and Earth.

Current Limitations, Future Research and Bibliography

Current Limitations

- The dust sensor was not of the highest quality.
- The materials used to build the self-cleaning wiper system were fragile.

Future Research

- Testing the solution on a large-scale solar farm and collecting results.
- Using a more dependable dust sensor.
- Use solar panel as a dust sensor.
- Use AI and images to detect dust and automatically activate the self-cleaning solar panel system.
- Use more robust materials such as a 3D printed parts.

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