Photovoltaic Soiling Sensor

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Design Problem

To create a sensor that detects soiling levels on industrial solar panels to maximize cleaning efficiency, thus minimizing solar energy loss.

Background and Motivation

Figure 1. "Clean Solar Panel vs. Soiled Solar Panel." Solar Panel Cleaning Services

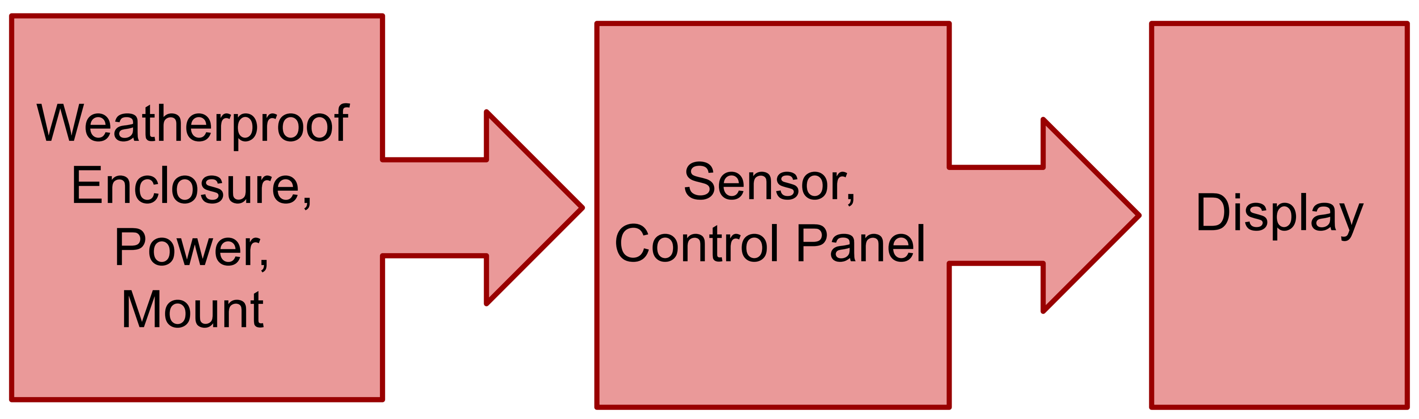
Soiling is defined as the accumulation of dirt, dust, and other pollutant particles onto the surface of solar panels (Figure 1).

- Soiling leads to $670,000,000 losses annually in the field of solar energy[1]
- Current sensors cost > $5,000[2]

Design Criteria

Design Criteria	Target Value
Cost	≤ $500
Accuracy	±5% of soiling level
Size	< 10 ft^3 (avg. car trunk size)
Power Source	0% drawn from solar panel
Ease of Use	Works with any size/mounting variation of solar panel
Durability	- Weatherproof (water, dust, wind) - Resistant to high temperatures (250 °F) - Product lifetime ≥ 1 year
Position	0% sunlight blockage
Precision	2 significant figures

Design Components



Device

The design uses photoresistors to compare the intensity of light through clean and soiled halves of a glass pane that simulates the surfaces of nearby solar panels.

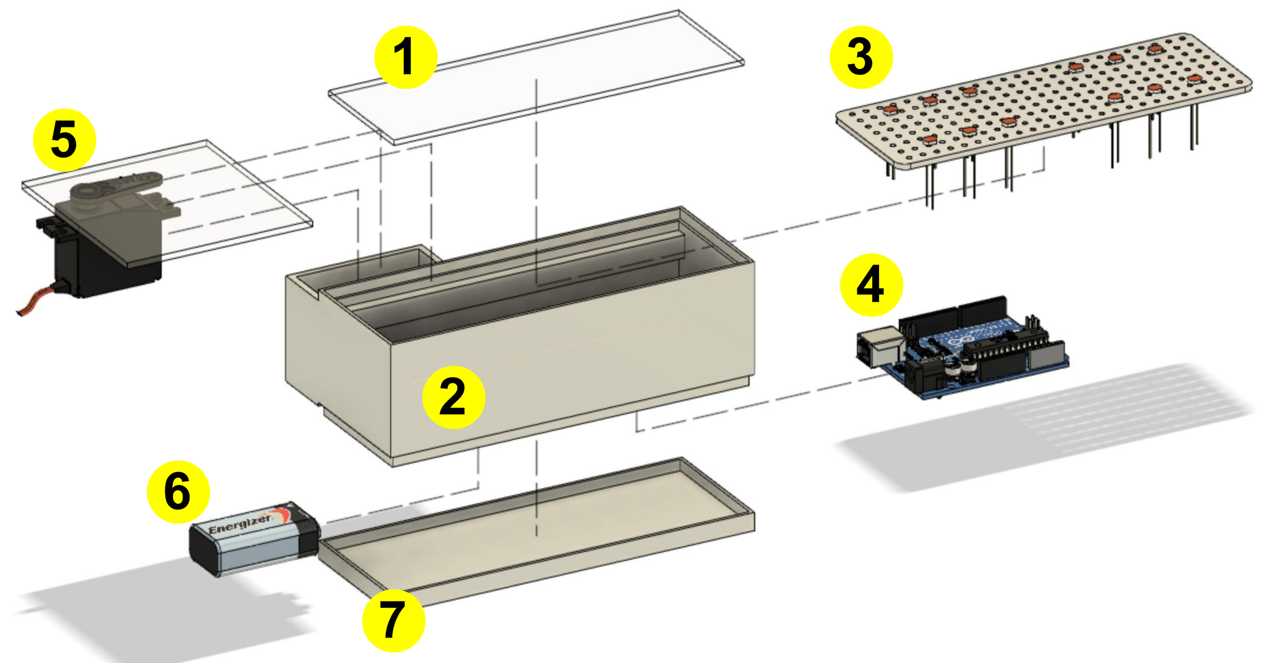


Figure 2. Exploded View of Design Assembly

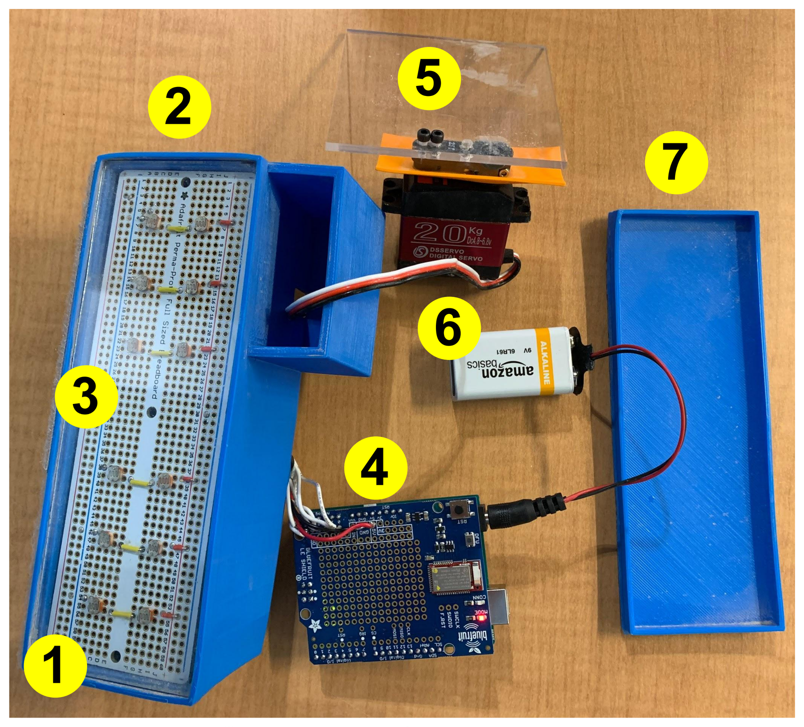


Figure 3. Final Design Assembly

Components:

1. Glass pane
2. Weatherproof box
3. Photoresistor circuit
4. Arduino with Bluetooth module
5. Servo motor with acrylic clean panel cover and weatherproof cover
6. 9V battery
7. Weatherproof box cap

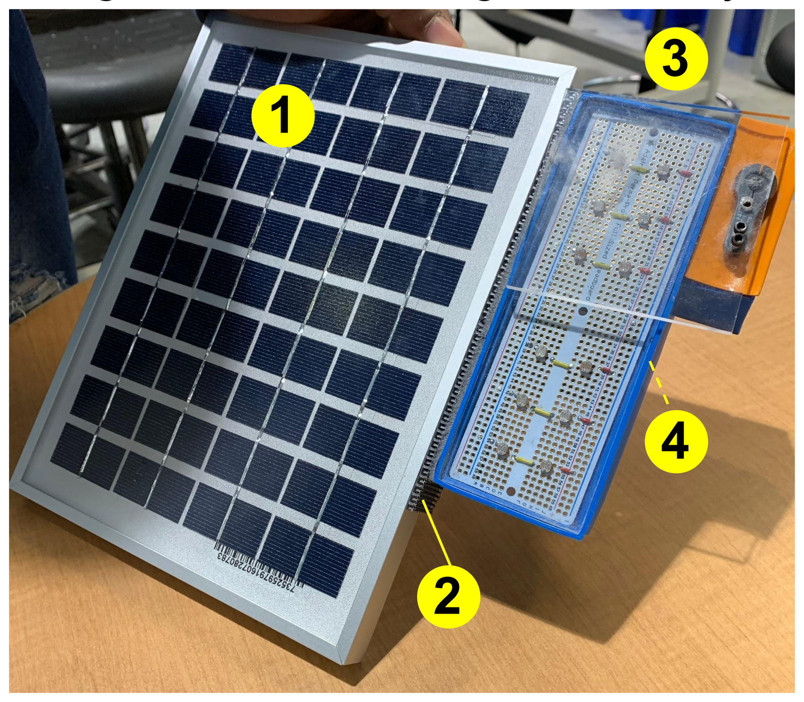


Figure 4. Implemented Design

Implementation:

1. Solar panel
2. Velcro for mounting
3. Soiling sensor
4. Wireless data transmission through Adafruit Bluetooth LE Shield and Adafruit app

Testing

Tests were conducted under simulated conditions to determine product durability and soiling measurement accuracy.

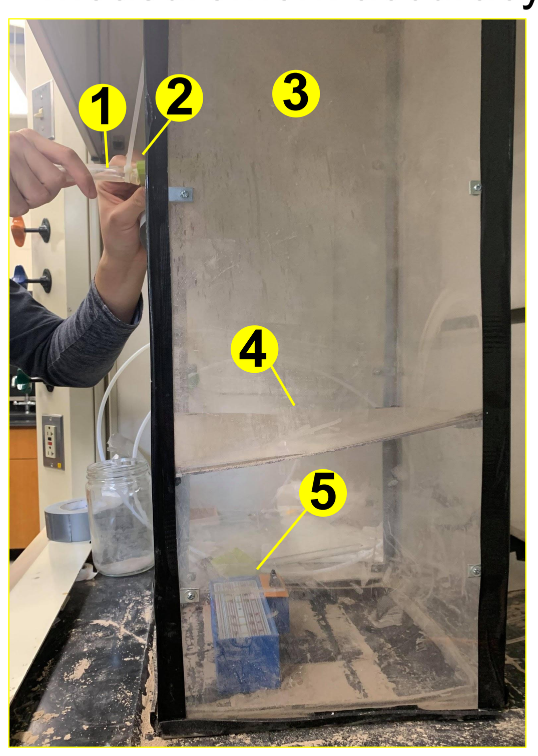


Figure 5. Soiling Chamber

Detection test setup:

1. Air Pump
2. Soil Deposition Funnel
3. Soil in mid air (soil storm simulation)
4. Soil sifter (to refine soil)
5. Soiling Sensor
6. Sample microscope slide to determine % soiling loss (Figure 6)

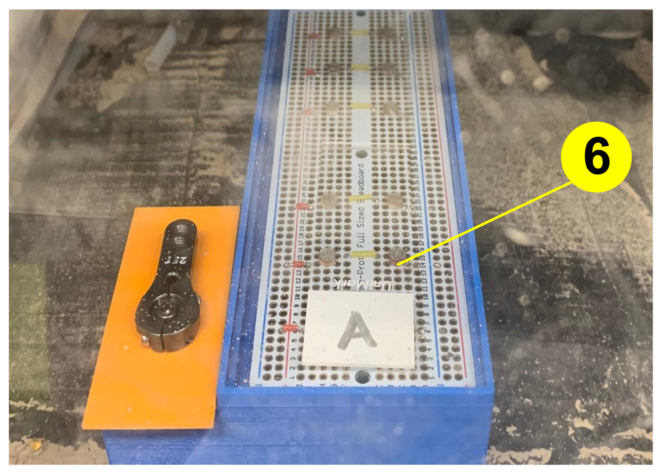
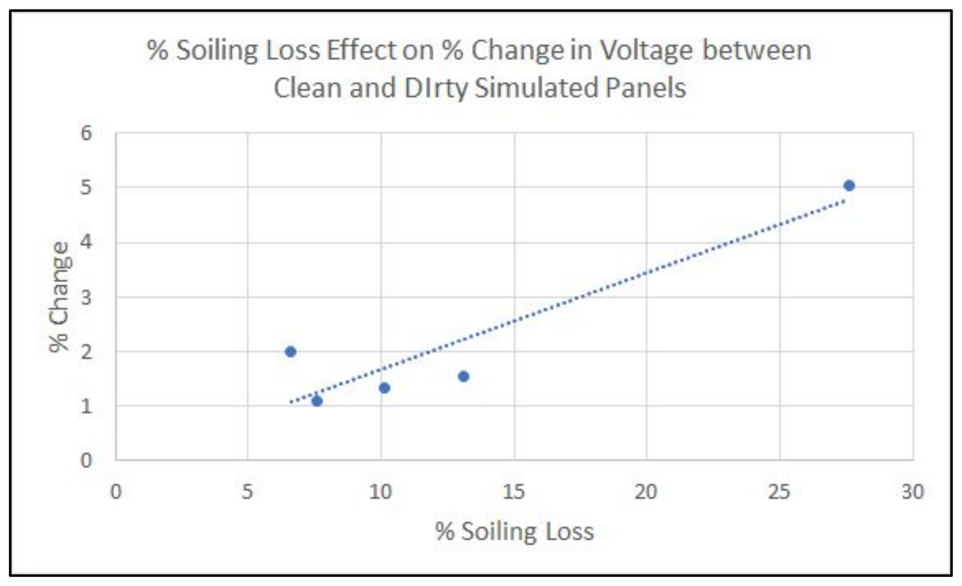


Figure 6. Microscope Slide to Determine Soiling Percentage

Testing Results

Results show a linear correlation between voltage and soiling loss, indicating that soiling-induced photoresistor variation is a reliable method to quantify soiling levels.



Graph 1. Standard Calibration Line for Sensor

% Change in Voltage = 17.61 * (% Soiling Loss) - 8.05

Equation 1. Best Fit Calibration Line

Criteria	Test/Method	Result
Durability	1. **Waterproof** - Water submersion test (measured volume penetrated) 1. **Windproof** - Force test (simulated force with weights, measured force with scales and force meters) 1. **Heatproof** - Heat test (heated device in oven at 140° F)	1. **Minimal leakage** from corners and top, **~0.5 mL water** seeped from sides 2. Withstands **1.835 lbs** vertically; **20 lbs** horizontally 3. **Minimal warping, electronics** remain **functional**
Position	**Sunlight blockage** - Measured shaded area with measuring tape (% shaded)	0% blockage of light

Conclusion

- An optimal sensor was created to **detect soiling** and **optimize** cleaning schedules.
- The device fulfills the main design criteria of **durability, cost, accuracy,** and **ease of use**.
- Future Objectives:
  - Create an enclosure with higher heat-resistance
  - Utilize optical sensors with higher sensitivity
  - Implement this device in large industrial solar farms

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