Automated Cleaning System for Solar Panels

ECE 445, Spring 2022

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Team 10
# Table of Contents

## Introduction
- Problem 3
- Solution 3
- Visual Aid 3
- High-Level Requirements 4

## Design
- Block Diagram 5
- Physical Design 5
- Cleaning Subsystem 5
- Power Subsystem 6
- Control Subsystem 6
- Tolerance Analysis 7

## Cost Analysis and Schedule
- Cost of Labor 7
- Cost of Parts 8
- Schedule 8

## Discussion of Ethics and Safety

## References

1. Introduction
   a. Problem

As solar panels are constantly exposed to the outdoor elements to achieve maximum efficiency and performance, the natural dust in air or pollutants from nearby settlements can cover the surface of the photovoltaic arrays with particulate matter that negatively affects their power output.[x] Current methods to remove this contamination are laborious and require human intervention to physically remove the dirt and dust which increases operation costs of solar farms. In applications where solar panels are installed on rooftops, cleaning can also be difficult as it will be left to the homeowner who may not be able to easily access the panels without specialized equipment.

b. Solution

An automated system which can detect decreased power output due to dirt coverage will be able to deploy a cleaning spray followed by a wiper to remove contaminants from the solar panels. This system can also be utilized to clear snow in cold climates by activation of just the wiper. Remote control of the wiper mechanism will also be possible for manual cleaning if needed in spite of the output readings being tracked by the system itself.

c. Visual Aid
d. High-Level Requirements

i. The microcontroller must have the ability to remotely activate the cleaning of the solar panel and have access to the current data from a web-based interface.

ii. The current sensor must be able to read the current from the solar panel which is then sent to the microcontroller where it will be stored and kept to compare the data over a number of days.

iii. The cleaning of the solar panel with wiper and sprayer must automatically trigger when the current output reaches a threshold of 65%-75%[x] of the max output for a period of a few days.

iv. Solar panel power extracted is highly stabilized removing fluctuations in voltage and current allowing for sufficient charging of batteries.

2. Design

a. Block Diagram
The power subsystem will take power from the solar panel and have it go through a buck converter which steps the voltage down to 6V to be used to charge the source battery that is used to power the cleaning subsystem. The 6V step down will then go through a second buck converter to have the voltage step down to 3.3V that will be used to power the current sensor of the power subsystem. The powered microcontroller is then used to control a relay that controls the pump and motor of the cleaning subsystem which will be powered by the source battery. It will also receive data from the current sensor and keep track over a period of days to determine if time and power loss threshold is met. The data will then be available on a web-based interface. The pump and motor will wait for the relay to allow for a voltage input and have them run for a period of time for cleaning.

b. Physical Design

![Circuit Diagrams]

*(Will need to finish circuit diagrams as parts are finalized and brought to project standards)*

c. Cleaning Subsystem

Receives power input from the charged battery of the power subsystem which is controlled by the microcontroller relay. This is to trigger the liquid pump to spray cleaning solution on the solar panel if predetermined conditions are met. Motor will then be triggered and move the wiper down the solar panel to clean the dirt off to return the solar panel back to top efficiency.

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Verification</th>
</tr>
</thead>
</table>


1. Have 0V at the input of the pump and motor when cleaning is not needed
2. Have 6V run to the pump and motor for a controlled time (*need to know exact time*) to clean the system

1A. Measure with an Oscilloscope that no voltage is reaching the pump and motor when cleaning is not needed
2A. Measure that when ... voltage is supposed to be reaching the pump and motor it is and within a +/- % (*need to work on exact*)
2B. Read motor specs and determine how long it will need to run to reach the entire length of the solar panel 32.5 inches +/- 3 inches

**d. Power Subsystem**

DC-DC converter to extract steady power from solar panel. Current meter and associated electronics to gather data for microcontroller to track power output. Charging circuitry for long-term storage batteries will also be included. The power of the source battery will be used to power the pump and motor of the cleaning system controlled by a set threshold from the microcontroller and relay input. The DC-DC converter will stabilize a 3.3V output which will be used to power the current sensor and microcontroller.

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Determine that the current meter is properly reading current and sending the correct data</td>
<td>1A. Use a known power source to give a known voltage and current to test the ability and accuracy of the power reading of the current sensor +/--%%&lt;br&gt;1B. When the current sensor is correct and the ability is there send the data to the microcontroller and determine if the output remains the same through data transmission</td>
</tr>
</tbody>
</table>

**e. Control Subsystem**
Microcontroller and associated interconnections to provide wireless data to communication subsystem, obtain power output data from sensing subsystem, and signals to activate cleaning mechanism through relays. This is powered from the DC-DC converter 3.3V output, which then will allow us to control a relay that will stop power from reaching the cleaning subsystem until requirements are met.

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Receives the current readings from current sensor system on the solar panel cables</td>
<td>1A. When we have both the sensor and microcontroller have the sensor read a known current from a known power source</td>
</tr>
<tr>
<td>2. Controls relay and doesn’t allow power through when power is not needed in pump and motor</td>
<td>2A. Measure the pump and motor when power is supplied to relay to check that there is no power output</td>
</tr>
<tr>
<td>3. Controls relay and allows power to pump and motor when cleaning is wanted</td>
<td>3A. Measure the pump and motor when power is supplied to relay to check that there is power input</td>
</tr>
<tr>
<td>4. Wirelessly transmit message to App or E-mail</td>
<td>4A. Check if message is received by App or E-mail notification within a certain delay of data being processed on microcontroller</td>
</tr>
</tbody>
</table>

f. Tolerance Analysis

i. A point of potential risk in the project is differentiating between cloud cover and dirt build up as cloudy days may appear as a dirtied panel to the program triggering a false cleaning which would waste stored energy and resources.

ii. While our system strives to be self-sufficient in power via batteries, we may find that excess energy could be sent to a larger bank or load to prevent damage to the DC-DC converter operating at no load.

iii. Calculation for percentage loss of solar panel:....

iv. Power output of battery to compare with power loss of solar panel
3. Cost Analysis and Schedule
   a. Cost of Labor
      i. The average salary (in the 2019-2019 academic year) for an Electrical Engineer graduate from UIUC is $79,714, and the average salary for a Computer Engineer graduate is $96,992. We will use the average of those two values in our calculations which is $88,353.
      ii. $88,353 / 50 weeks / 40 hours per week = $44.18 per hour
      iii. $44.18 * 15 hours per week * 7 weeks = $4,638.90 per Student
      iv. $4,638.90 * 3 students = $13,916.70 for student labor
      v. Machine Shop Estimated Labor = TBD
      vi. Total Cost = Student Labor + Machine Shop Labor = TBD
   b. Cost of Parts

<table>
<thead>
<tr>
<th>Description</th>
<th>Part Number</th>
<th>Quantity</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcontroller</td>
<td>ESP32</td>
<td>1</td>
<td>$4.00</td>
</tr>
<tr>
<td>Windshield Wiper</td>
<td>RX30224</td>
<td>1</td>
<td>$9.00</td>
</tr>
<tr>
<td>Battery</td>
<td>ML4-6</td>
<td>2</td>
<td>$25.64</td>
</tr>
<tr>
<td>Sprayer Module</td>
<td>CMXCAF190640</td>
<td>1</td>
<td>$8.98</td>
</tr>
<tr>
<td>Current Sensor</td>
<td>BYT-VAM-033</td>
<td>1</td>
<td>$18.98</td>
</tr>
<tr>
<td>MCU Board (2nd Board)</td>
<td>ESP32-C3-DevKitC-02</td>
<td>1</td>
<td>$9.00</td>
</tr>
<tr>
<td>Relay Module</td>
<td>B00LW15A4W</td>
<td>1</td>
<td>$6.79</td>
</tr>
<tr>
<td>Solar Panel</td>
<td>HSP100D-L</td>
<td>1</td>
<td>$89.14</td>
</tr>
<tr>
<td>Input Regulator Chip</td>
<td>LM317T/LF01</td>
<td>1</td>
<td>$2.31</td>
</tr>
<tr>
<td>Microcontroller Voltage Supply Chip</td>
<td>LD29080PT33R</td>
<td>1</td>
<td>$1.58</td>
</tr>
<tr>
<td>Diodes</td>
<td>1N4007-T</td>
<td>10</td>
<td>$1.98</td>
</tr>
</tbody>
</table>
## c. Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Austin</th>
<th>Alex</th>
<th>Prudhvie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 7</td>
<td>Help with PCB design/ Go in and finalize design with machine shop</td>
<td>Finalize PCB design</td>
<td>Help with PCB and understand how to program ESP Chips</td>
</tr>
<tr>
<td>Week 8</td>
<td>Get PV characteristics of the solar panel</td>
<td>Characterize cleaning subsystem components (sprayer, wiper motors) with waveforms.</td>
<td>Test if current sensor is outputting correct readings to secondary board (Use arduino test kit)</td>
</tr>
<tr>
<td>Week 9 (Spring Break)</td>
<td>Document Check</td>
<td>Document check (datasheets)</td>
<td>Document Check</td>
</tr>
<tr>
<td>Week 10</td>
<td>Helping with prototyping/ Working on solar output threshold for data transmission</td>
<td>Prototyping for circuit design</td>
<td>Work on setting up web interface; Get current sensor interfacing with secondary board</td>
</tr>
<tr>
<td>Week 11</td>
<td>Work with known power source and check outputs of power subsystem</td>
<td>Prototyping for circuit design</td>
<td>Work on interfacing main board with secondary board</td>
</tr>
<tr>
<td>Week 12</td>
<td>Start connections with main microcontroller</td>
<td>Finalize testing of cleaning system interactions</td>
<td>Work on processing data and activating relay from microcontroller</td>
</tr>
<tr>
<td>Week 13</td>
<td>Connect solar panel with power subsystem and test</td>
<td>Extreme testing for operation conditions</td>
<td>Work on sending data and notification to web</td>
</tr>
</tbody>
</table>
4. Discussion of Ethics and Safety

a. IEEE 802.11 - Wireless communication standards 

i. As our sensing meter and microcontroller rely on wireless communication, we must follow regulations set forth by IEEE and the FCC to prevent interference with networks of equipment nearby.

ii. Preferably, our project will use WiFi for the communication standard.

b. IEEE 1013 - Lead-acid battery selection, charging, testing, and evaluation of batteries for PV systems [3]

i. Sealed lead-acid batteries will be used to store energy for the project and possibly for a demonstration of connections to larger storage systems. We will need to size our components in the power subsystem as well as the batteries themselves to ensure safe and efficient operation of the project.

c. IEEE 1562 - Solar array and battery sizing for stand-alone PV systems [1]

i. This standard concerns systems where solar panels are connected to batteries in a stand-alone system much like our project. If this cleaning system were to be utilized on a solar farm which is grid connected, we would have to slightly modify some components concerning the charging and conversion sections of the power subsystem.

d. IEEE Code of Ethics Implications

i. Our project looks “to strive to comply with ethical design and sustainable development practices” [2] and “to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems” [2].

ii. In developing technology which is new and innovative, there is an obligation that one serves to the community to ensure it is beneficial for all those involved and aims to improve current situations.
5. References

