Automated Cleaning System for Solar Panels

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Team 10

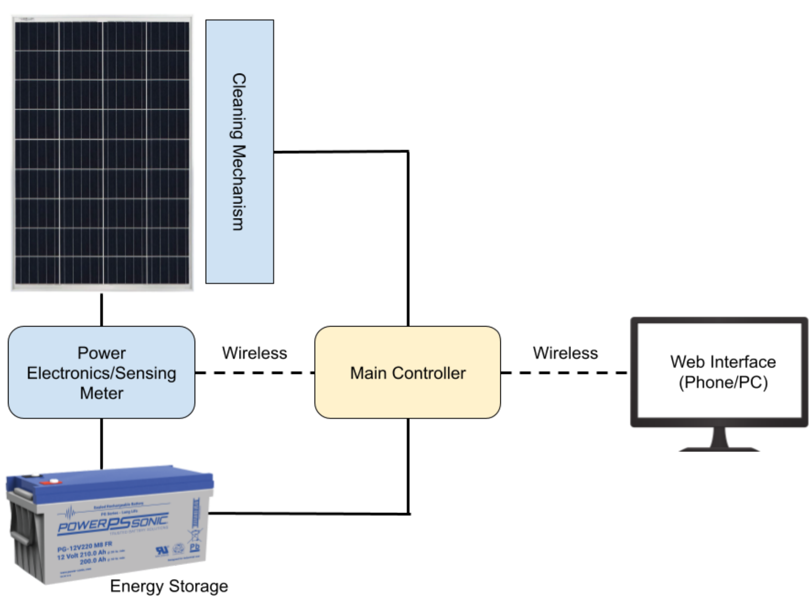
1. **Introduction**
    a. Problem

    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. 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. Ability to remotely activate the system from a web-based interface (either through PC or mobile phone) and receive email notifications about potential need for cleaning.

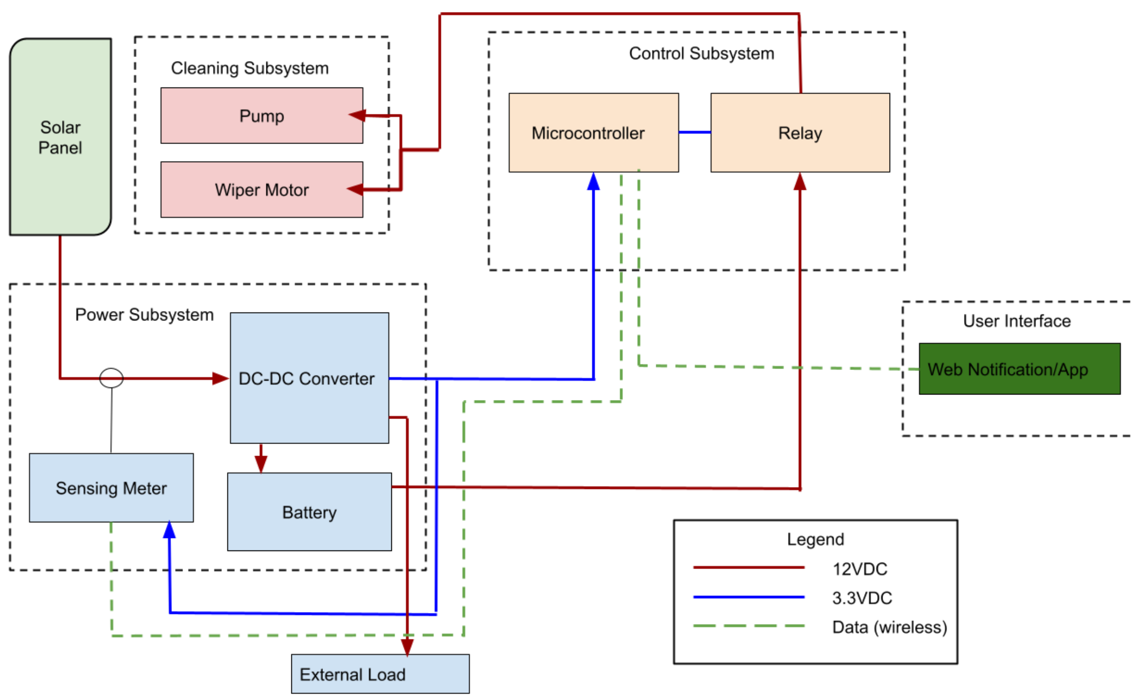
ii. System tracks power output data over lengths of time saving to an easily accessible repository for monitoring of conditions

iii. Automatically activate when output falls below specified threshold (between 25-35%) and show increase in power due to removal of contaminants.

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



b. Subsystem Overview

i. Cleaning Subsystem - Receives input from the microcontroller relay to trigger pump and spray cleaning solution on solar panel if predetermined conditions are met. Wiper will then be triggered and move down the solar panel to clean the dirt off to return the solar panel back to top efficiency.

ii. Power subsystem - MPPT DC-DC converter to extract maximum 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.

iii. 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.

c. Subsystem Requirements

i. Sprinklers will spray, when told to either automatically from output data and microcontroller or remotely by the owner/user, a cleaning solution before the wiper is initiated to allow for cleaning of dust off of the panel. A small water pump will be used to bring liquid to the sprinklers and allow for liquid to be applied to the panel. We will use motors to move a wiper up and down the solar panel to clean off anything that is obstructing the solar panel.

ii. With remote access to the data we will be able, from any location, to get an alert when the power reaches a threshold, determined by us and the tradeoff power. This will allow us to make sure that the system is cleaning properly and that the solar panel is returned to normal power output. Also, we expect to be able to monitor the output data over a few days to track build up.

iii. A battery system will be charged from the solar panel in a way that does not significantly impact the power output and when fully charged it will remain until it needs to be used to power the cleaning system. MPPT electronics will be used to ensure that the system is charged efficiently and provide the cleaning system with sufficient power (a minimum of 12VDC for actual cleaning equipment and 3.3VDC for microcontroller)

iv. From a current meter we will be able to determine the output of the solar cell and depending on the threshold that we want to set, as losing enough power that is more than the power it takes to clean, will allow us to see it as reasonable to clean. Data of the solar panel output will also be tracked to detect build-up over the course of several hours/days.

v. A microcontroller will be used to gather data from the current meters and calculate the possibility that dust or other debris is blocking the solar panel and will activate the cleaning system made up of the wiper and/or sprinkler. From the decrease in current we are able to determine the efficiency drop once the efficiency drops so much the cleaning process will be initiated. The decrease in current should be drastic and overall trends should be measured instead of short time periods to differentiate between cloud cover and actual dust and other debris. Additionally, the microcontroller should be able to identify the other current sensors + associated electronics by their ids so that many sensors can connect to one central microcontroller. Notifications will also be sent wirelessly to the end user. The microcontroller also will be able to activate relays which allow for the 12VDC inputs to the sprinkler and wiper motors to be controlled with 3.3VDC.

d. 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.

3. 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
   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

   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” [1] 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.