Automated Self Cleaning Solar Panel

Project Proposal
ECE 445

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February 12, 2014

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1. Introduction

1.1 Statement of Purpose

According to the Solar Electric Power Association (SEPA), the loss of solar power due to the accumulation of dirt, bird excrements, leaves, snow etc. can reach up to between 15-20% [1]. Solar panel owners, both commercial and residential, often tend to overlook this aspect of solar panel maintenance. This project was chosen to design a cleaning system that would tackle this problem, along with being efficient, cheap, and easy to use.

1.2 Objectives

1.2.1 Project Goals:

- Design a mechanism to detect obstructions on solar panels causing significant loss of power
- Design a cleaning mechanism that runs across the length of the panels
- Program the system so that it also cleans on a scheduled basis
- Improve overall solar panel efficiency

1.2.2 Functions:

- Enable the cleaning mechanism once an obstruction has been detected
- Be able to distinguish between whether the obstruction is physically present on panel or not (e.g. cloud shading)
- An indication whether the soap/water tanks need refilling

1.2.3 Benefits:

- Reduction in cleaning costs
- Easy installation
- No soap or water residue left over
- Cleaning done even in absence of owner

1.2.4 Features:

- One-time installation
- Effective wiping system with efficiently paced motion
- Easily replaceable wipers

2. Design

2.1 Block Diagrams

Table1. Block Diagram Legend

Electrical Power	→
Data	→
Mechanical Action	- - - →

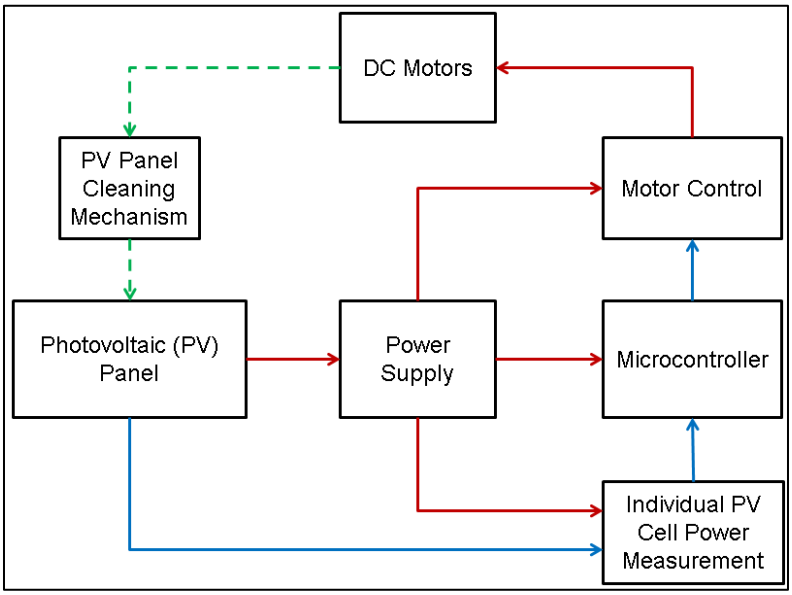

Figure 1. Top Level System Diagram

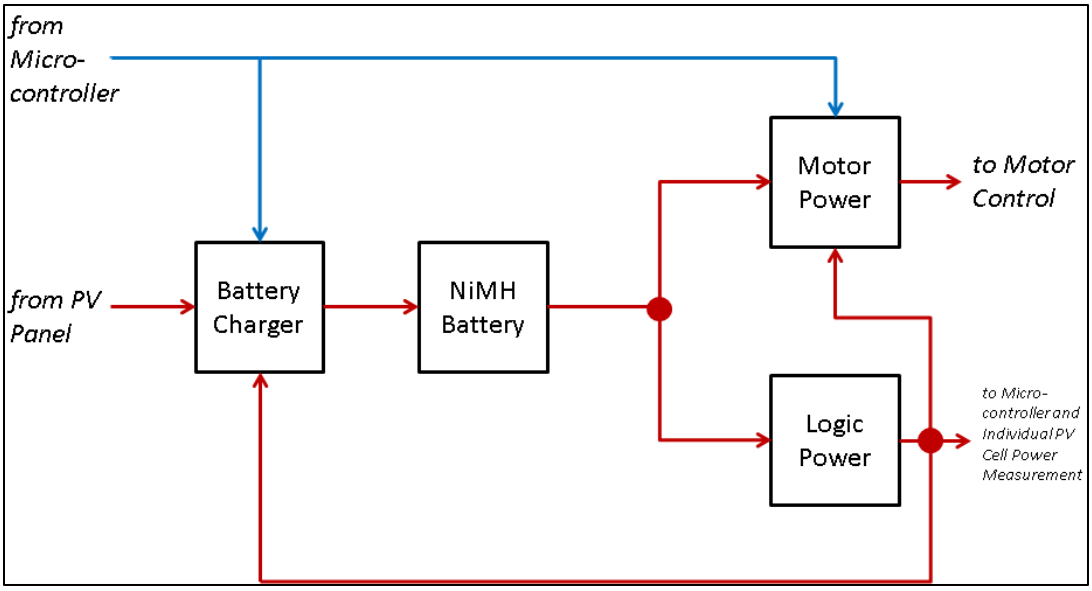

Figure 2. Power Supply

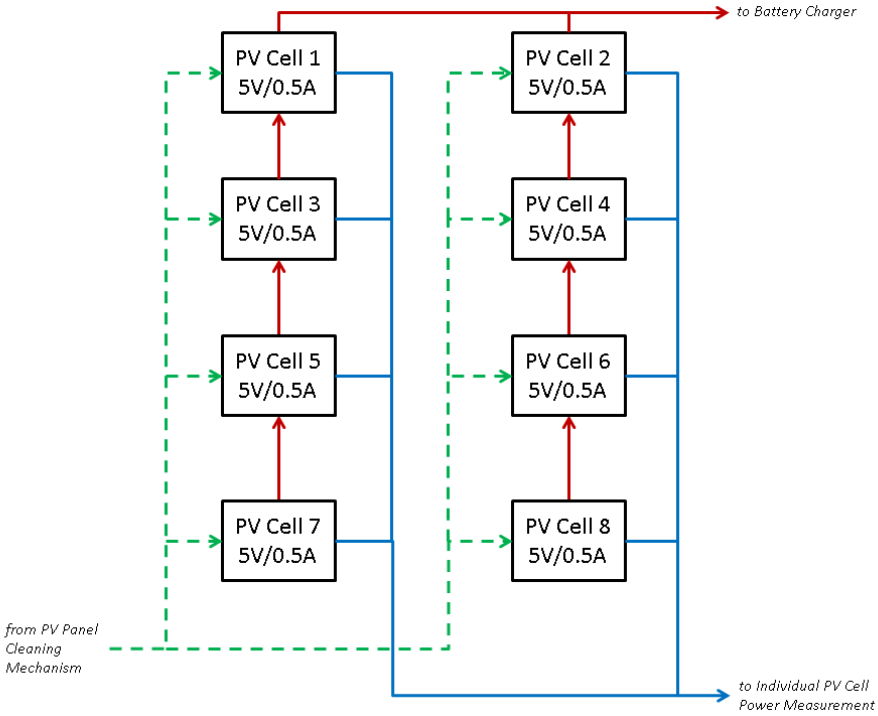

Figure 3. Photovoltaic Panel Diagram

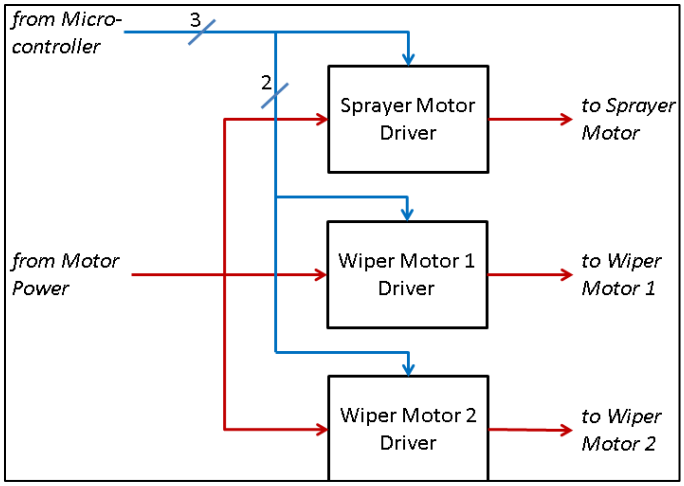

Figure 4. Motor Control

2.2 Block Diagram Descriptions

2.2.1 Micro-controller

The microcontroller unit will consist of a MSP430-G2553 chip. It will have two functions implemented. The first will be to control the duty cycle of the power from the solar panel to the battery unit and the duty cycle of the motor power. The second function will be to control the motor after receiving signals from the sensors.

2.2.2 Photovoltaic (PV) Panel

Eight 2.5W, 5V solar cells will be connected to provide 20V and 1A output to the Battery Charger. Two sets of four cells will be connected in series. Those two sets will be connected in parallel. Each cell will have a bypass diode for improved performance during shading.

2.2.3 Power Supply

- Battery Charger

The battery charger unit is made up of two linear regulators, a MSP430, a quadruple operational amplifier, and a DrMOS Module with LDO. This is a continuation of a project from Professor Pilawa, Chris Barth, and Yann-Tyng Lin for EOH.

- Battery

The NiMH batteries were chosen for their memoryless effect, 500 to 1000 rechargeable instances, and amp-hours enough to support both the motors and the sensors. [2]

- Motor Power

+12VDC from the Battery will be stepped down to a nominal +6VDC by a switched-

mode DC/DC buck converter. All three DC motors will use the +6VDC from the Motor Power.

- Logic Power

The Microcontroller and any other integrated circuit will be supplied from the Logic Power. This will be a linear regulator IC. The Logic Power will change +12VDC from the battery and supply +5VDC to logic level loads including the Microcontroller, Motor Control, Motor Power, Individual PV Cell Measurement and the Battery Charger.

2.2.4 DC Motors

Three DC motors will drive the cleaning mechanism. Two of the motors will drive the linear actuators for the wiper bar. The third motor will drive the pump for the sprayer. The motors will be supplied by the Motor Power and controlled via the Motor Control.

2.2.5 Motor Control

Each DC motor will have it's own separate control circuit. The two wiper mechanism motors will be each controlled by transistors in an H-bridge. The sprayer motor only needs transistors in a half-H-bridge. Control signals to gate the bridge circuits will come from the Microcontroller. Power for the Motor Control will come from the Motor Power in the Power Supply.

2.2.6 PV Panel Cleaning Mechanism

The cleaning mechanism will have two main parts. First, the wiper mechanism, which wipes the PV Panel in the linear motion, will be fabricated by the ECE Machine Shop. The wiper mechanism consists of two screw type linear actuators driven by one DC motor each. A wiper bar connects the two actuators across the PV Panel and is driven by the screws' rotation. Second, the sprayer will be a premade kit with some modification for mounting on the PV Panel. The sprayer will be a simple DC motor pump sprayer with a water reservoir.

2.3 Overall Requirements

- The 5V solar panels need to be able to charge the 1.2V AA 2300mAh NiMH batteries.
- Batteries must supply the power of all the drivers, motors, and the voltage sensing unit.
- The DC motors must have enough torque to eliminate the obstructions using the wiper and sprayer

3. Verification

3.1 Testing Procedures

Table 2. Testing Procedures

Block Name	Requirements	Verification
Power Supply (micro-controller)	Adapt to different input current. Able to supply enough power to the whole system.	Two buck converters are going to be built. 20V input power supply is to be used to charge the batteries, and the batteries needs to be able to supply the 6V DC motors.
PV Panel	Supplies $20W_{Peak}$ and 16V ± 20% for the combined panel configuration	Test combined power output of entire panel by measuring current and voltage at peak luminosity on the panel. A power resistor bank will be connected to test no-load to full-load (20W) conditions.
Master Micro-controller	Control the power supply. Gather information from the individual PV cell measurement unit and initiate the DC motors.	Voltage measurement from each PV cell is compared with a standard voltage. Once a cell unit sends lower voltage reading, the micro-controller will send signals to the motors.
DC Motors	Operate from 3-9VDC to achieve goal wiper speed. Combined motor current does not exceed 2A	While running a panel cleaning cycle, for the supply voltage of 3-6V, combined motor current will be measured by clamp on ammeter. At no time will combined motor current exceed 2A.
Cleaning Mechanism	Wiper moves from top of the panel to the bottom of the panel in 2-3 seconds. Panel height will be approximately 20 inches.	Time the wiper motion from top to bottom of solar panel.
Individual PV Cell Measurement	Incase the output power of a cell falls more than 10% with respect to neighbouring cells, the cleaning mechanism needs	Perform voltage and current measurements on individual cells to check whether a signal needs to be sent back to the microcontroller.

	to be activated.	
Motor Control	Wiper motors turn in a direction to drive the wiper blade down to the end of the solar panel. Position feedback sensors then trigger the motor to reverse direction to return to the top starting position. The wiper motors stop when triggered by position feedback sensors Sprayer motor actuates to spray the panel while wiper motors are rotating.	Satisfy conditions to start a panel cleaning. Wiper motors should have proper direction of rotation for wiper motion. Sprayer motor should cause rated sprayer output.

3.2 Tolerance Analysis

For individual obstructions, the system must initiate cleaning when there is at least a 10% drop in power over one minute on one cell only. This will be tested by applying maximum luminosity to the entire PV panel. Then, a completely opaque material measured to cover at least a 10% area of one PV cell will cover that cell for one minute. This should initiate a cleaning cycle for each cell tested. Therefore the individual PV cell measurement is the most important factor in this project.

4. Cost and Schedule

4.1 Cost Analysis

Table 3. Total Labor Cost

Name	Hourly Rate ($/hr)	Total Hours Invested (hr)	Total ($) = Hourly Rate x 2.5 x Total Hours Invested
Yann-Tyng Lin	50.00	150	18750.00
Yousaf Abdul Salam	35.00	150	13125.00
Terry Green	35.00	150	13125.00
Total	120.00	450	45000.00

Table 4. Total Parts Cost

Item	Part Number	Quantity	Cost/unit ($)	Cost ($)
Motor Drive IC	DRV8837	3	1.00	3.00
Wiper Blade	-	1	10.00	10.00
Solar Cells	-	8	8.00	64.00
NiMH battery	NH15BP-2	1	10.00	10.00
PCB	-	1	20.00	20.00
Sprayer Kit	http://wetstorm.com/washerkit.html	1	25.00	25.00
Microcontroller	MSP430G2553	1	13.00	13.00
Linear Regulator	TPS77301	2	2.00	4.00
Capacitors, resistors, and inductors	-	-	-	10.00
DC Motor	Mabuchi RF370CA-15370	2	5.00	10.00
Power Sensors	INA223	8	5.00	15.00
Gate Drivers	IR2117	2	3.00	6.00
Total	-	-	-	190.00

4.2 Schedule

Table 5. Schedule

Week	Terry	Yann-Tyng	Yousaf
2/10	Finalize and hand in proposal	Research power supply, battery charger parts	Research solar panel specifications needed for motors

2/17	Order solar panel cells, battery, Design DC/DC converter	Learn to program TI Launchpad (MSP 430)	Prepare cleaning mechanism specs for machine shop and order
2/24	Design Individual Cell Power Measurement Circuit	Design Review, Design battery charger	Design motor control for wiper motors
3/3	Motor Control for Sprayer motor	Assembly of cleaning mechanism	Eagle PCB Design and ordering
3/10	Solar Panel Performance Testing (breadboard)	Power supply testing (breadboard)	Motor performance testing (breadboard)
3/17	Solar Panel Performance Testing (complete assembly/PCB)	Power supply testing (complete assembly/PCB)	Motor performance testing (complete assembly/PCB)
3/24	Spring Break	Spring Break	Spring Break
3/31	Mock-up Demo	Tolerance Analysis	Verification of Specs
4/7	Fix remaining issues	Fix remaining issues	Fix remaining issues
4/14	Ensure completion	Ensure completion	Ensure completion
4/21	Prepare Demo	Prepare Presentation	Prepare Paper
4/28	Demo and Presentation/ starting final paper	Demo and Presentation/ starting final paper	Demo and Presentation/ starting final paper
5/5	Final Paper	Final Paper	Final Paper

5. References

[1] What Is The Scientific Effect of Dirt Build Up on Solar Module Performance?, *Sol Cleaner*. [Online]. Available: http://solcleaner.com/faq-2/

[2] Proper Care and Feeding of a NiMH Battery, Battery Stuff. [Online]. Available: http://www.batterystuff.com/kb/articles/battery-articles/proper-care-and-feeding-of-a-nimh-battery.html