Solar Powered Three-phase Motor

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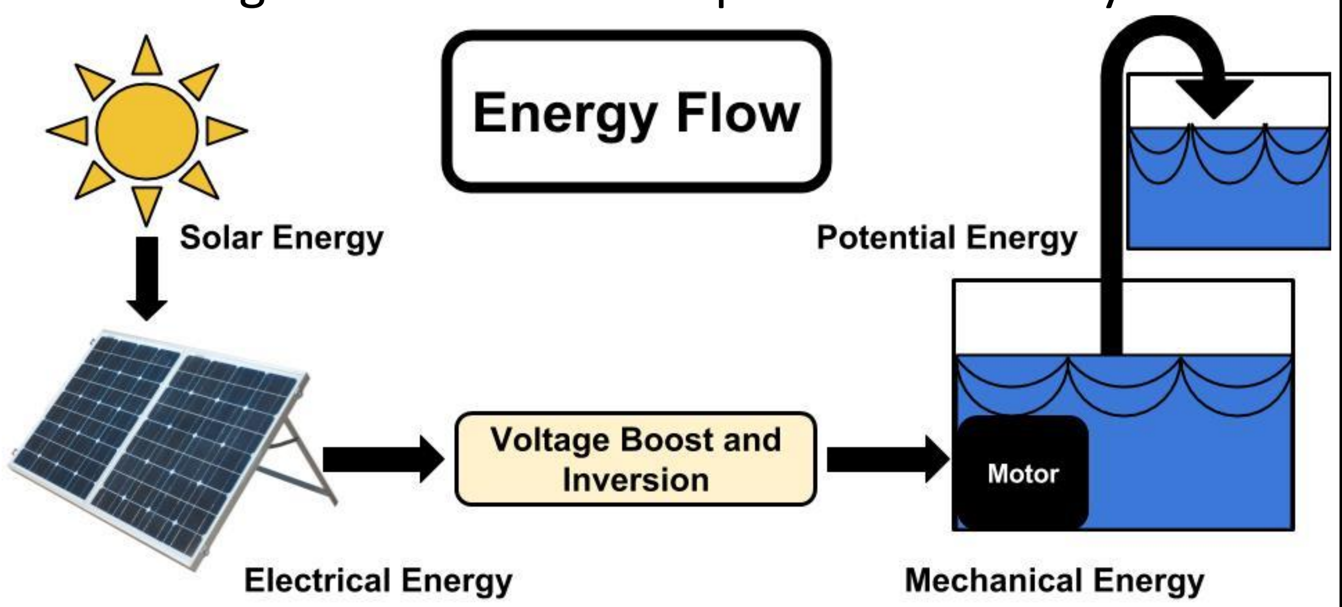
Problem Statement

Our goal is to use solar panels to produce three-phase power at maximum efficiency, without reliance on grid power, and under varying sunlight.

Our system:

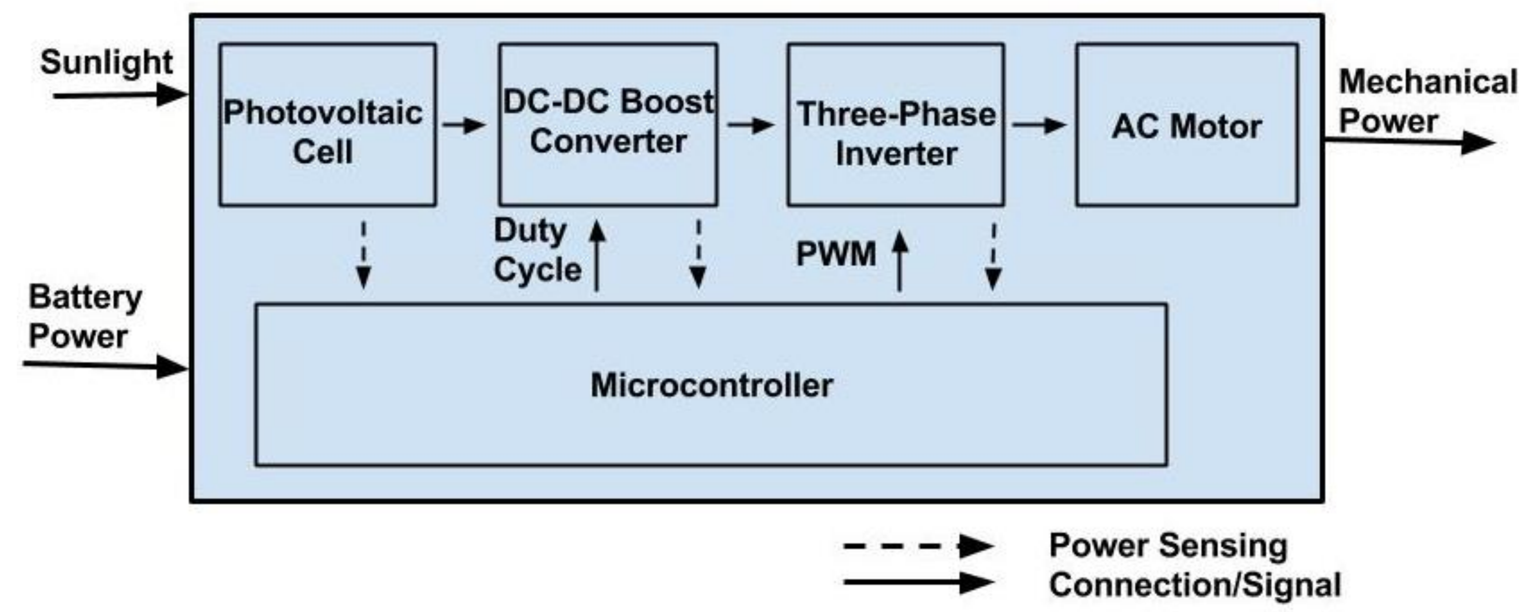
- is functional in a variety of outdoor conditions that can change instantaneously
- addresses the problem of effective energy storage by converting solar energy to mechanical energy immediately upon capture
- provides off-grid power to a mechanical load while taking into consideration power availability



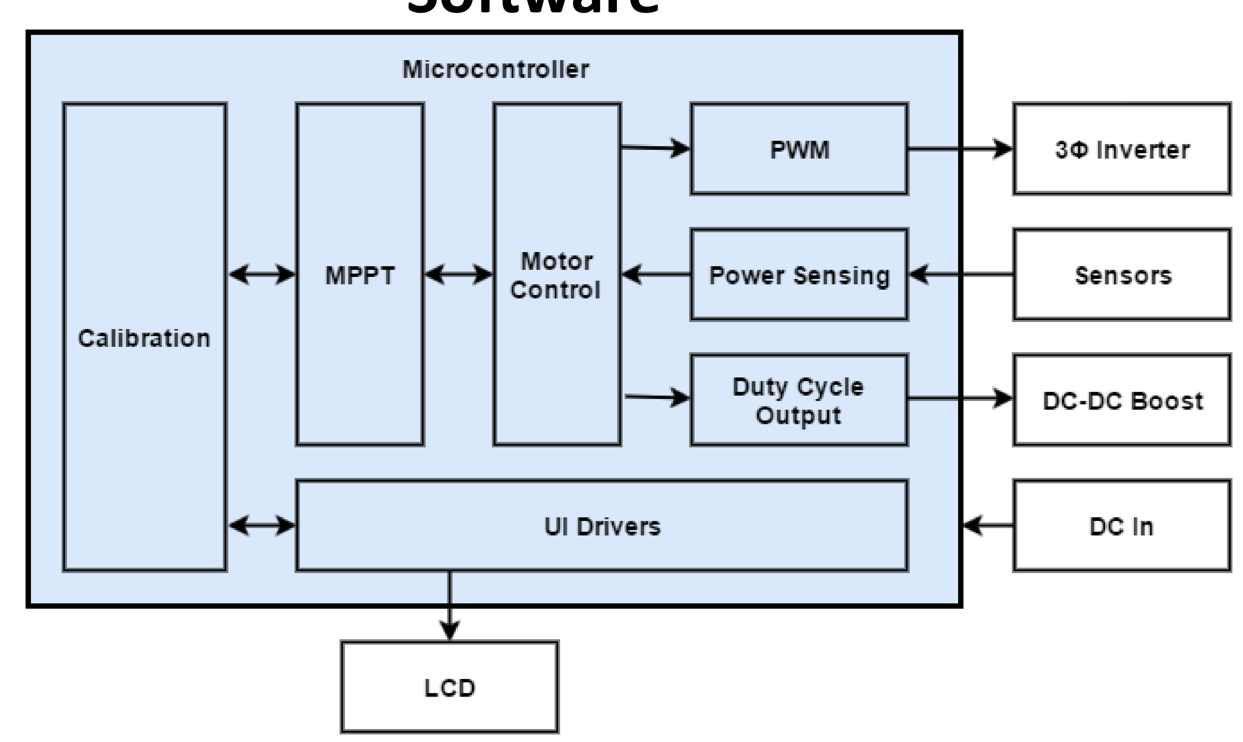
High-level diagram of energy flow for our design

System Diagrams

Hardware



Software



Block diagrams of hardware and software modules for our design

Design Summary

The system receives sunlight incident on the **photovoltaic cells** and outputs mechanical power with a **three-phase motor** under varying sunlight conditions. The **DC-DC boost converter** boosts the voltage from the solar panels to the input of the **three-phase inverter**, which outputs three AC voltages. Sensing input allows the **microcontroller** to measure the power available to the system, as well as the power delivered to the **motor**, so as to determine the frequency and voltage output to the motor.

The microcontroller **senses** the DC output of the solar panels, as well as the AC input to the motor, and computes a **maximum power point tracking** (MPPT) algorithm. This decides the most efficient **duty cycle** (controls the output voltage of the DC-DC boost converter) and **pulse width modulation** (PWM) frequency for the three-phase inverter. The calculated power input and output are displayed on the LCD screen.

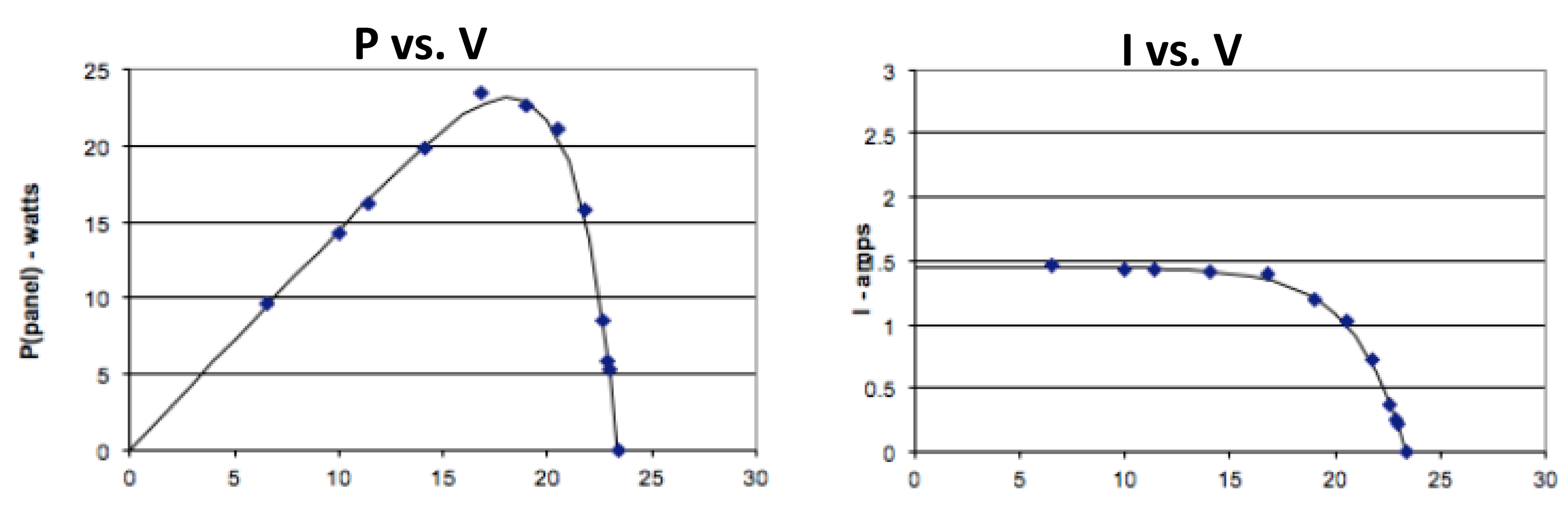
Potential improvements to our design include:

- rigorous calibration of the motor's operating regime
- self-sufficiency (no reliance on external power)
- safer housing for electrical components

Testing and Evaluation

Solar Panels

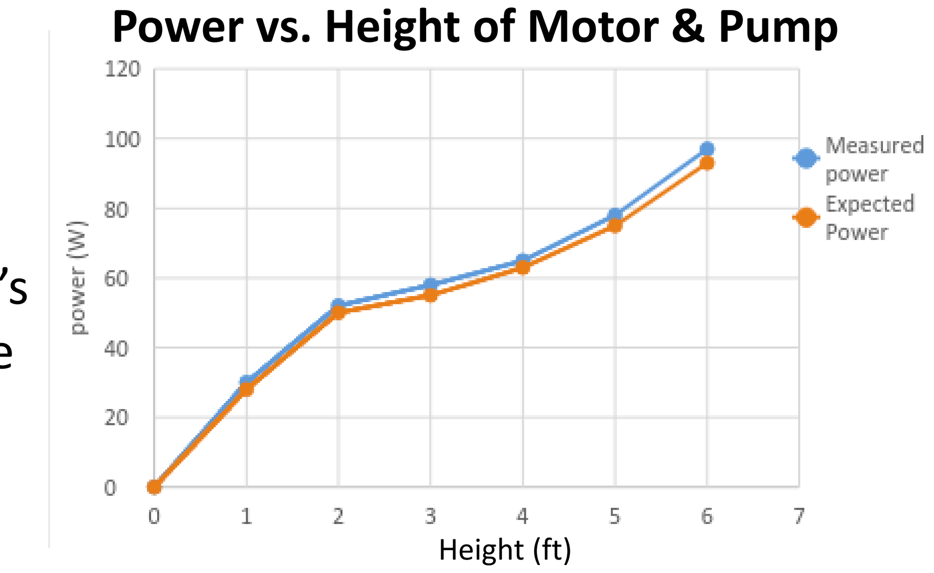
The four solar panels were constructed by previous senior design groups, and the figures on the right show the resulting power and current vs. voltage curves produced from testing the output on a sunny day. This information will be used to help calculate maximum efficiency based on varying levels of sunlight.



Power vs. Voltage and Current vs. Voltage plots for solar panels

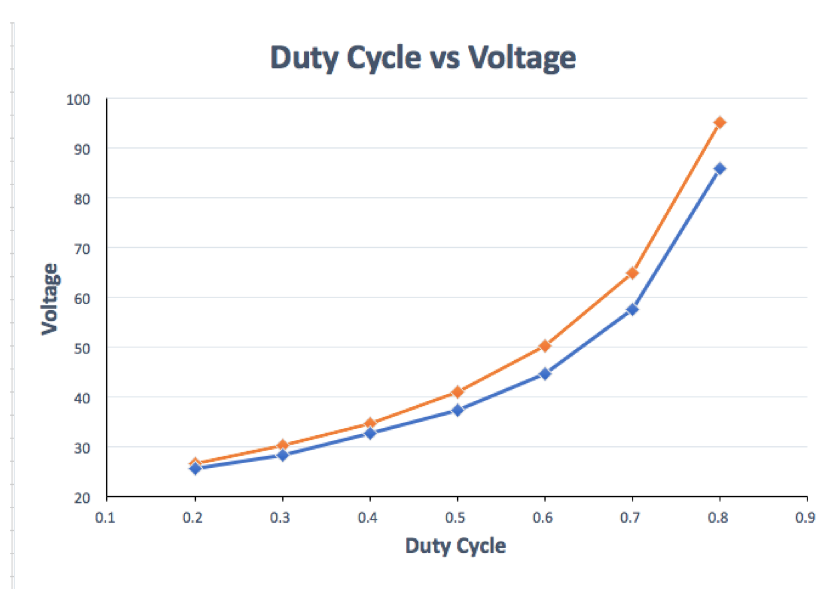
Sensing

Both AC and DC sensing circuits were tested using known input voltages and currents that correspond to the range of 0 to 3.3V, the voltage levels required for the microcontroller's analog-to-digital conversion. We measured the output with a multimeter and adjusted the sensing levels using potentiometers according to expected voltage and current levels.



DC-DC Boost Converter

We tested the boost converter at a range of input voltages, from 3.3 V DC to 93V DC, as well as the duty cycle range from 10 to 80% to ensure expected output. Our goal was to reach an efficiency of 90%, which can be achieved using MOSFETs with lower inherent resistance and inductors rated for higher voltages.



Boost Converter D/V curve

Three-Phase Inverter

The three-phase inverter takes PWM input from the microcontroller and outputs boosted PWM with a peak voltage level supplied by the DC-DC boost converter. We tested its functionality by varying the input voltage and frequency and measured the output with an oscilloscope.

Motor Control

We first implemented motor control using potentiometers to simulate changing conditions in sunlight levels, and therefore the power measured at the output solar panels. The next step is to test the algorithms with the integrated system by simulating shade to ensure that the rate of water pumping lessens with less incident sunlight.

Motor

We tested the motor first with the three-phase inverter at 70V AC and 30Hz. We found that the rate of water pumped increased when the voltage output of the DC-DC converter and the frequency of the PWM were increased, and that the rate of water pumped decreased when the hose was held higher. The plot above shows the measured and expected power at pumping heights of 0 to 6 feet.