SELF-SUSTAINABLE SOLAR STREETLIGHT

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Introduction

Objective

The goal of our project is to design and create a portable, self-contained, self-sustaining and user-friendly streetlight that can be set up anywhere with minimal effort, independent of the power grid, and will function similarly to a commercial streetlight in providing light during periods of darkness.

To create such a streetlight, we will be using a LED lighting fixture, powered by a rechargeable battery, which in turn will be charged via power supplied by a solar panel. One major disadvantage that plagues the adoption of solar-powered streetlights in the real world is the life cycle of the rechargeable battery used to store power (Expanded upon further in the 'Background' section below). Over time, the battery's efficiency will degrade, requiring it to be replaced in order to return the streetlight to maximum capacity. Hence, in order to make our streetlight's design as user-friendly as possible, we will be including a subsystem which will monitor and transmit the battery's power levels. The user will be able to use a mobile/web application in order to see data from this monitoring subsystem, allowing them to gauge the current battery level. The major focus of our project will revolve around three things: (1) identifying the combination of specifications for the solar panel/battery/LED light that best allow the three to work together while still maintaining the portability requirement of the streetlight, (2) building appropriate hardware subsystems (such as a solar charge controller or an LED driver) to ensure proper and smooth operation by the three main components, and (3) designing a battery monitoring subsystem, a transmission subsystem and a mobile/web app through which the user can observe the battery's charge level with ease. Building a pole for the streetlight, however, will not be included as part of the focus of this project.

Background

Streetlights powered by electricity have been around for nearly 140 years, since arc lamps were first used for lighting streets in cities such as Paris and Los Angeles. While the lighting fixture used in these streetlights have changed near continuously over time - from arc lamps to incandescent bulbs to high-intensity discharge lamps to LED lights - the electricity used to power these streetlights has almost always come from the electrical grid. While directly using solar panels to power streetlights is hardly a new idea - numerous patents have been filed on the concept, including some as early as 1978 - solar-powered street lighting, while undoubtedly seeing use as novelty appliances and in smaller communities, have yet to achieve widespread use in major urban regions on the city-wide scale. While directly using solar panels to power streetlights is hardly a new idea - numerous patents have been filed on the concept, including some as early as 1978 - solar-powered street lighting has been used as novelty appliances in smaller communities and have yet to achieve widespread use in major urban regions on the city-wide scale completely independent of the power grid. There are three major reasons for this. Firstly, and most importantly, solar street lights have a very high initial setup cost compared to conventional streetlights, which already have their infrastructure readily set up in the form of the electrical grid. Secondly, using solar panels has various downsides, such as less power generated during shorter days (which coincide with longer nights, when light is needed the most) and requiring cleaning from dust, snow, etc in order to continue functioning effectively. Thirdly, the degradation over time of the battery's charge-discharge life cycle means the solar streetlight will either become less effective over time if not properly maintained. Our project is targeted towards providing alleviations to the second and third problems. As described in the 'Objective' section, we have a user-friendly mobile/web monitoring application that allows the user to observe the battery charge levels in the streetlight. This serves two purposes: the user can make informed decisions on how much power they can expect from the streetlight (which addresses the second problem), and can notice battery degradation well in advance (which addresses the third).

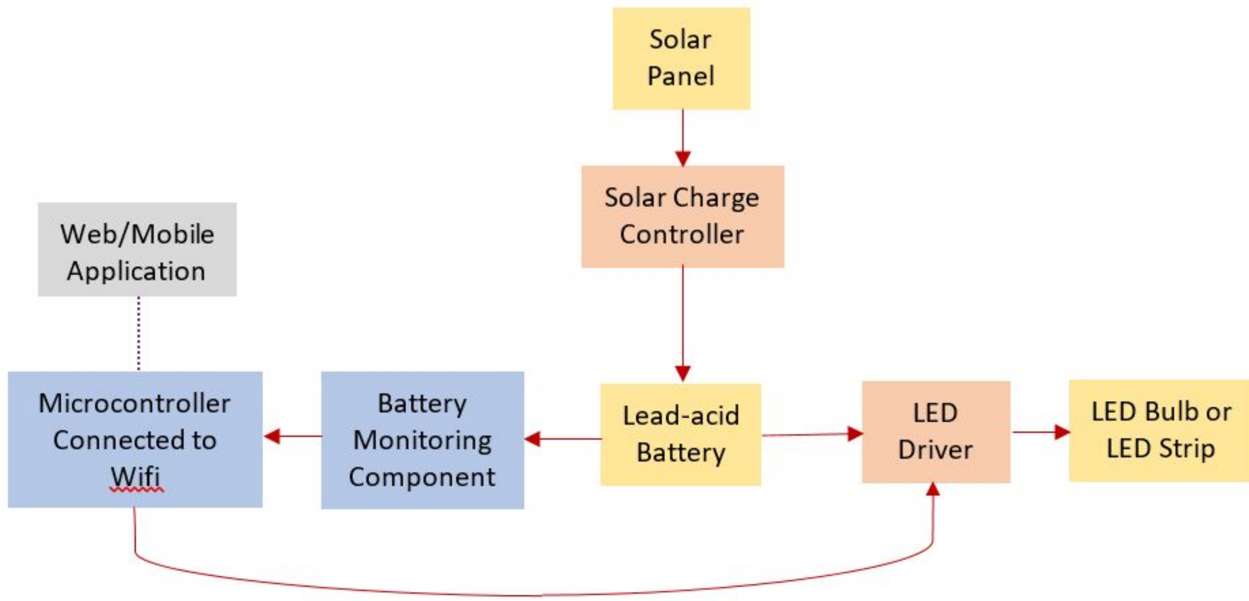
High Level Requirements List

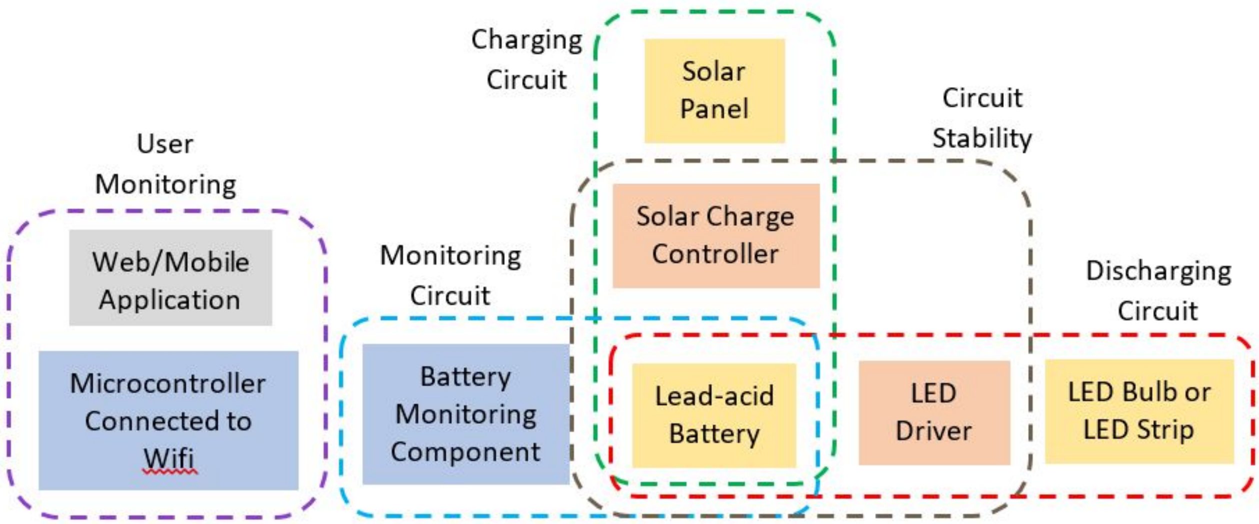
- The streetlight must be self-sustainable in the sense that:
  - It should operate on power provided by the battery alone.
  - The battery should be charged via power from the solar panel.
- The streetlight should be operational for extended periods and provide light when it is dark or night-time.
- The streetlight should have a mechanism for monitoring its battery level, likely via communication with a mobile/web application**.**

Design

Block Diagram

The main subsystems constituting the focus of this project are: User Monitoring, the Monitoring Circuit, Circuit Stability, Discharging Circuit, and the Charging Circuit.





Functional Overview

Charging Circuit:

I. Solar Panel - The solar panel is the sole power source for the streetlight. It will provide the Solar Charge Controller node with voltage that will charge the battery. There will be enough power to keep this system powered (light) for around 12 hours a day, for at least seven days.
II. Lead-acid battery - The battery must keep the circuit powered for seven days, even during the night when no live solar power is available. In particular, a sealed lead-acid battery is preferred due to its low price, low maintenance and reliability.

Requirements: As of now, we are planning to use solar panels that provide between 80 - 120 W of power: either two 60W solar panels or one 80W solar panel. This requirement will be better defined once the exact hours for powering the streetlight are decided. We are also looking at procuring a lead-acid battery with a capacity of about 480W-hours of energy.

Discharging Circuit:

I. LED Bulb/LED strip - The LED bulb or strip will be powered through the solar panel and will emit light. The streetlight should be able to be lit in the dark as well.
II. Inverter - An inverter circuit is needed in order to convert the DC that was produced by the solar panels to AC that will be used to power the LED bulb/strip.

Requirements: An ideal source is one that is brightest with the lowest watt consumption. Most options we are looking at consume between 25-35W to produce 3000 lumens of light. An inverter to convert DC to AC will be needed as well.

Circuit Stability:

I. Solar Charge Controller - The solar charge controller, also known as the solar regulator, represents our ‘charging circuit’. It regulates the amount of charge going from the solar panel to the battery and is the intermediate circuit between the two. In particular, the solar regulator is necessary to prevent the battery from being overcharged and to monitor if the voltage is too low to supply (causing damage to battery if attempted to discharge when not possible).
II. LED Driver - The LED driver represents our ‘discharging circuit’. It regulates the amount of power going to the LED bulb/strip from the battery, and thus, protects the LEDs from fluctuations in voltage and current. Because the LED’s requirements will change with

temperature, the LED driver allows the appropriate amount of power to get through to the LED bulb/strip. Without it, the LED can fail due to heat or instability. The LED Driver will also be responsible for turning the lamp on and off. It will get a signal from the microcontroller about when to turn on and off and function accordingly.

Requirements: A Solar Charge Controller IC and LED Driver PCB will be utilized for the completion of the Solar Charge Controller and LED Driver.

Monitoring Circuit:

I. Battery Monitoring Component - The Battery Monitoring Component will be the circuit that retrieves the relevant information to be sent to User Monitoring. A gas-gauge IC will monitor the lead-acid battery's State-Of-Charge (SoC). The analog signals from the IC will be converted to digital signals using an ADC (Analog to Digital Converter) and sent to the microcontroller.

Requirements: A Gas Gauge IC and an ADC chip will be needed for the battery monitoring component.

User Monitoring:

I. Microcontroller - The microcontroller will be utilized to send the information from the Monitoring Circuit via WiFi to the Web/Mobile Application via a web server. A WiFi Chip will be used. The microcontroller will also query a web api for the location sunrise/sunset times and send a signal to the led driver to turn on/off the lamp.
II. Web/Mobile Application - The web/mobile application will be user-friendly and will allow a user to remotely check the battery status (how much power the system has) by communicating with a web server that is connected to microcontroller.

Requirements: A Web Server, Wifi Shield, Relay Box are necessary in order to complete the sending of information from the microcontroller remotely to the web/mobile application.

Risk Analysis

While the battery component is the central focus of the project, it should be quite surmountable given the abundant resources on the issue. It is the user monitoring section of the project that may prove to be the greatest risk to the successful completion. While it may seem easy enough to describe in words, it involves considerable challenges such as converting analog measurements to digital signals, sending the digital signals in an appropriate format over a wi-fi network, and building from scratch a mobile/web application that receives these signals over the wifi network, parses them correctly, and displays them in a human-understandable format. Not only do the three of us lack experience on the particular topics this section entails, but there do not appear to be any readily accessible resources to help us understand and implement all the necessary subsystem components. These two factors in combination make the user monitoring section the largest risk to the successful completion of our project.

Ethics and Safety

Of all the components in our project, the lead-acid battery has the greatest number of safety considerations associated with it.

- Lead-acid batteries are contain lead, a toxic metal, and sulphuric acid, a corrosive agent; and hance must be disposed of carefully.
- If lead-acid batteries are discharged too much or too fast, they can potentially be damaged.
- Certain temperatures and overcharging also cause lead-acid batteries to fail, requiring preventive measures to be taken. In some older models, extreme conditions can even result in the battery exploding.
- Lead-acid battery leakage has the potential to cause serious damage clothing and human skin, as well as other components such as wiring.

The manner in we will deal with this is by creating appropriate precautions to control how the battery is charged and discharged. The solar charge controller will control the voltage going into the battery, and the LED driver, although for the LED, controls also the rate of discharge of the battery. General electrical hazards exist as well. If the direct current produced by the solar panels is not properly converted to alternating current (if the circuits are not properly integrated), electrocution, fires and other such problems might occur. Also if the casing is not made well and the wires are not insulated properly it may cause issues in the functioning of the streetlight.

Another issue is that of the weather effects on our streetlight. It is intended for the streetlight to be self-sustainable and be placed outside without being attached to another device. If the attachment of the solar panels and components on the streetlight is not designed properly, it is plausible that high winds can loosen or even completely detach these solar panels or components and cause damage to nearby items or people (after all, the streetlight is expected to function with people nearby). We must keep IEEE Ethics Code #1 and ACM Code

#1.2 in mind as our streetlight can affect people's safety if not constructed properly. Rain or the moisture in the air can create mold, rotting, or corrosion, which can cause additional concerns if the streetlight is attached to a home or shed. In the winter, snow is another issue to be considered. If the solar streetlight is not able to sustain the weight of snow piling up on it, as solar panels are generally quite light, the structure can collapse. To prevent weather-related issues, we will take preventive measures and create proper casing and insulate wires.

The inclusion of wifi networking in our project opens up a major ethical concern. While the internet is doubtless an incredibly powerful tool in supplying near-limitless information with virtually no required effort, its usage exposes us to invisible yet extremely serious threats to our privacy. By broadcasting data from the streetlight via the wifi network and requiring the user to use a mobile/web application to access this data, we may potentially open up the user to security risks from malicious entities who may attempt to steal information from the user's phone or computer by hacking or masquerading as the streetlight's wifi link. Exposing the streetlight's users to such danger would violate the IEEE Code of Ethics #1 ("*to accept responsibility in making decisions consistent with the safety, health, and welfare of the public...*") and #9 ("*to avoid injuring others, their property, reputation, or employment...*") and ACM Code 1.2 ("*Avoid Harm to Others*"). In order to prevent such cases from happening, we must ensure that proper network security measures are in place to prevent leakage or theft of the user's information.

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