Solar Powered Rechargeable Battery Pack with Controllable Voltage Output

ECE 445 Project Proposal - Spring 2018

Team 55 - Zhuohang Cheng, Zihao Zhang

TA: Bryce Smith

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1 Introduction

1.1 Objective

The goal of this project is to develop battery pack that could be self-recharged by solar cells and outputs controllable voltages at different levels. The solar cells would be mounted on the system in a portable box. The output of the battery is controlled and monitored by microcontroller and is adjustable and visible for users. Users could select the prefered voltage level on the user interface. This project aims to provide user oriented battery with portability, flexibility, and endurable capacity for the increasing use of battery today. By using batteries with different capacities and small configurations on the design, this system could be applied to various situations like electrical vehicles, cell phones, or smart home batteries.

1.2 Background

Modern society and industry thrive on top of electricity. Electrical energy could be generated from and converted to various source of energy. It has the most sophisticated system to transmit the energy safely and efficiently. However, even though the uses of batteries are increasing and diversifying, the technology of battery is stagnant. People today would really suffer such problems that the cell phone and the power bank has both run out of batteries, or something other than cell phone wants to charge from the power bank but there is no suitable voltage output. So, this system is developed in order to make better use of battery that could self-recharge and have the ability to output different voltage level to accord with different demand.

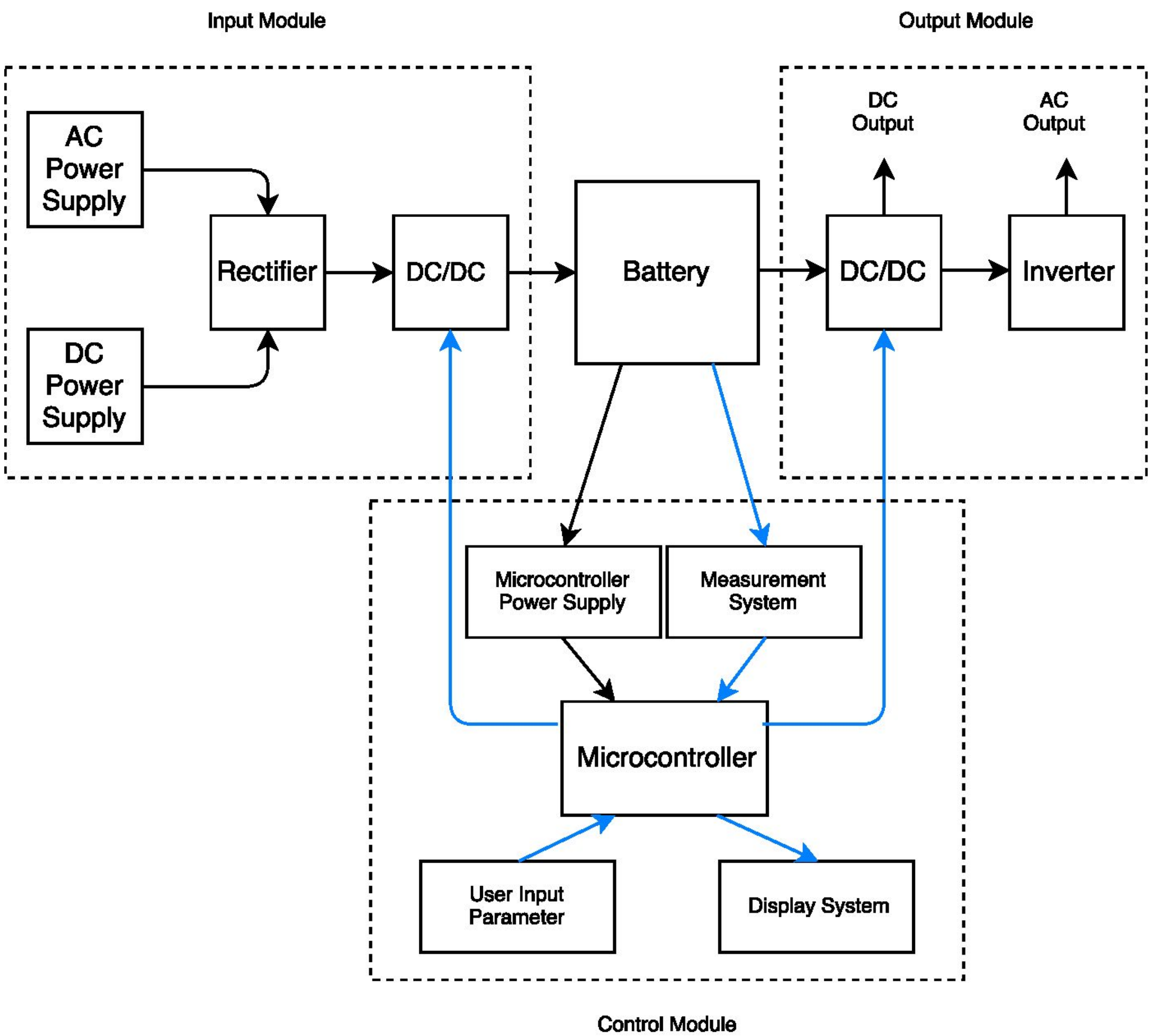
The system could apply to various situation. The system with a larger battery could be applied to electric vehicles. With self-recharging, vehicles could have greater endurance, and with the ability of outputting different voltage levels, the single system could be used as power source for driving, electrical devices on the vehicles, or mechanical operations.

1.3 High-level Requirements

- The solar panel must be mounted on the system and provide persistent power with sufficient light resources.
- The system could also be recharged from wall plug.
- The system need to be able to discharge 5V - 25V DC power, and 20V - 120V AC power.
- The system need to display the voltage, current, and power while charging or discharging.
- User could select desired output voltage level from the user interface.

2 Design

2.1 Block Diagram



2.2 Input Module

2.2.1 AC Power Supply

The AC power supply for our project comes from the 120 V wall plug. This AC input will go through a rectifier to convert into a DC voltage, and this DC voltage will be fed into a DC/DC converter to buck down (or boost up) to the desired voltage level for charging the battery.

2.2.2 DC Power Supply

The DC power source for our project basically comes from a solar panel. The solar panel will be surface-mounted on a box that contains our whole device. Similar to the AC power supply, the DC input from the solar panel will also go through a rectifier and a DC/DC converter.

2.2.3 Rectifier

The rectifier will convert the input AC voltage into a DC voltage and send this DC voltage into a DC/DC converter. For input DC voltage form the solar panel, this rectifier will also be able to output the same DC voltage.

Requirement 1: The Rectifier must be able to output a DC voltage with small output voltage ripple (less than 1%).

2.2.4 Input DC/DC Converter

The DC/DC power converter will be a buck-boost converter that can buck down or boost up the input voltage to the desired output voltage level. The topology we are considering about for this converter is flyback buck-boost converter. This converter will be controlled by a microcontroller using a feedback circuit.

Requirement 1: The converter must be able to handle a variable input voltage range (12-120 V DC).
Requirement 2: The converter must be able to output a constant DC voltage with small output voltage ripple (less than 1%).

2.3 Output Module

2.3.1 Output DC/DC converter

The output DC/DC converter will be similar to the input DC/DC converter. This converter will output a constant DC voltage based on user's requirements.

Requirement 1: The converter must be able to handle a variable input voltage range (12-120 V DC).
Requirement 2: The converter must be able to output a constant DC voltage with small output voltage ripple (less than 1%).

2.3.2 Inverter

The inverter will convert the input DC voltage into a sinusoidal AC voltage. According to IEEE THD Limitations, the total harmonic distortion of this inverter should be less than 5%.

Requirement 1: The inverter must be able to output a sinusoidal AC voltage with less than 5% THD.

2.4 Control Module

2.4.1 Microcontroller Power Supply

This device will power the microcontroller using the lead-acid battery pack. It will contain a voltage regulator that regulate the input voltage to the desired voltage level for charging the microcontroller.

Requirement 1: This device must be able to output a constant 5V DC voltage from a 12V DC input.

2.4.2 Battery Measurement System

This system contains some wattmeters and sensors that can monitor the voltage and current levels during the discharging process. This system will provide all the necessary data to the microcontroller that will control the DC gain of two DC/DC converters, as well as the LED display information.

Requirement 1: This device must be able to measure the voltage and current levels of the output power converter as accurate as possible.

2.4.3 Microcontroller

The microcontroller will collect all the data from the battery measurement system, and compare these data with user’s input parameters to determine the operation mode for both input and output power converters. In addition, it can also monitor the charging process to prevent batteries from overcharging.

Requirement 1: This device must be able to receive data and send proper instructions.

2.4.4 User Interface

This device includes a control panel for user to control the output power mode. The control panel will send the input parameters to the microcontroller. User can choose the output power mode (either AC or DC) and adjust the output voltage level (12 - 25 V DC, 20 - 120 V AC) based on specific requirements. It can also control the output current limit to meet the output power requirements.

Requirement 1: This device must be able to send the data to the microcontroller as accurate as possible.

2.4.5 Display System

This device is also part of the control panel that can display all the important information to the user. The microcontroller will send all the measured information to the display system.

Requirement 1: This device must be able to receive data from the microcontroller and display that information to the user.

2.5 Battery

The battery pack will be several lead-acid batteries connected in parallel. The rating voltage for charging the battery is 12 V. Care must be taken in order to prevent batteries from overcharging.

Requirement 1: The batteries must be charged with extreme caution as it may lead to an explosion hazard.
Requirement 2: The batteries capacity must be large enough for long-time outdoor activities (at least 5 hours).

2.6 Risk Analysis

Our major risk for this project is charging or discharging the batteries. The batteries we will use is the lead-acid battery which may cause a serious hazard if not properly handled. Over-charging a lead acid battery can produce hydrogen sulfide. The gas is colorless, very poisonous, flammable and has the odor of rotten eggs. Hydrogen sulfide also occurs naturally during the breakdown of organic matter in swamps and sewers; it is present in volcanic gases, natural gas and some well waters. Therefore, an SLA battery should be charged with extreme caution. When charging an SLA with over-voltage, current limiting must be applied to protect the battery. Always set the current limit to the lowest practical setting and observe the battery voltage and temperature during charge.

3 Ethics and Safety

The Lead Acid Battery we are going to use in the project will cause health and environmental concerns. As Engineers, it is our responsibility to disclose the potential harm of using this kind of batteries, and inform the proper method of recycling.
Health Concern: Lead is a toxic metal that can enter the body by inhalation of lead dust or ingestion when touching the mouth with lead-contaminated hands. If

leaked onto the ground, acid and lead particles contaminate the soil and become airborne when dry. The sulfuric acid in a lead acid battery is highly corrosive and is more harmful than acids used in most other battery systems. Contact with eye can cause permanent blindness; swallowing damages internal organs that can lead to death. In order to ensure safety, batteries need to be locked away from small children to avoid potential ingestion by them.

Environmental Concern: Lead contaminations would cause lots of problem. If they are not recycled properly, they can leak into the surrounding soil and air. This creates an exposure hazard. Sulfuric acid can enter the water system and contribute to acid rain, according to an August 6th, 2002 report by the Environmental Protection Agency (EPA). As this acid flows through the ecosystem, it poses various dangers to the animal and plant life, as well as the soil. Within precipitation, sulfuric acid accelerates the decay of structures and paints, wearing down buildings and landmarks. It also causes damage to trees and acidifies lakes and other water bodies. In the atmosphere, sulfates are among the particulates released into the air, which can harm the public health.

Safety Concern: Since this system could be dealing with high current that could cause electrocution, current and voltage limit need to be clarified for the users. A light indicating improper operations or a warning sign should be included.

4 References

[1] "BU-703: Health Concerns with Batteries." *Health Concerns with Batteries - Battery University*, batteryuniversity.com/learn/article/health_concerns.

[2] “BU-403: Charging Lead Acid.” *Charging Information For Lead Acid Batteries – Battery University*, batteryuniversity.com/learn/article/charging_the_lead_acid_battery.
[3] “Environmental Concerns With Sealed Lead-Acid Batteries.” LIVESTRONG.COM, Leaf Group, 17 Sept. 2011, www.livestrong.com/article/213685-environmental-concerns-with-sealed-lead-acid-batteries/.