LiFePO4 Battery Pack Per-Cell Management System

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System Overview

- Lafayette Photovoltaic Research and Development System (LPRDS)
  - 2kW solar energy system that converts high voltage DC to 120V AC RMS signal of 60Hz
  - Capstone project to introduce students to real engineering project issues and requirements
  - Multi-year multi team senior Electrical and Computer Engineering design project
CMS-2011 Project Overview
Why Balance?

- Extend useful lifetime
  - Or, not decrease the expected lifetime

- Increased health over lifetime

- Increased operational capacity

- Increase the accuracy of SOC calculations
Why Balance Our Way?

- Dictated by several factors:
  - Requirements
  - Physical limitations
  - Time constraints

- Design for simplicity:
  - Relatively simple implementation
  - Uses easy to gather information
  - Can be updated to reflect better cell characterization
Active Vs. Passive Balancing

- **Active**: Using capacitive or inductive loads to shuttle charge from higher charged cells to lower charged cells.
  - Is more efficient from a power perspective
  - Has scalability issues

- **Passive**: Bypasses cells (usually through a resistance) and burns off the excess charge from the cell.
  - Better large-stack scaling
  - Burn off can be significant
Hardware Design

- **Strict Physical Requirements**
  - Fit on top of a pack
  - Low enough to fit in rack
  - Interweave components between the cell terminals

- **Electrical Requirements**
  - High power path must handle up to 25 Amps
  - Minimize current drawn for circuitry
  - Electrical isolation for all communication signals
  - Bypass circuitry should bypass as much current as possible
Hardware Design – Temperature Analysis
Software Design – Cell Balancing Algorithm

• Based on monitoring for 50 mV differences in cell voltages

• Maximum and minimum charge decided by hard voltage thresholds

• Incorporates temperature measurements to protect against overheating
Software Design – State of Charge Algorithm

- Based on Coulomb Counting
- Uses data from the current sensor to sum the current over time
- Sum and sample period are output through I2C, and the user can calculate SOC by

\[
\frac{\text{Sum} \times \text{sample period}}{\text{Capacity} \ (A \times \text{Hr})} \times 100 = \text{SOC} \ (%)
\]
Simulation – Voltage Curves

Voltage Curves of Charge/Discharge of Pack with Blanacing

- 90% Initial SOC
- 25% Initial SOC
- 12% Initial SOC
- 10% Initial SOC

Voltage (V) vs. Time (hr)
Simulation – SOC Curves

SOC Curves of Charge/Discharge of Pack with Balancing

- 90% Initial SOC
- 25% Initial SOC
- 12% Initial SOC
- 10% Initial SOC
Simulation – Standard Deviation and Power
Conclusions

- Standard deviation of cell voltages is a fair metric of the effectiveness of the CBA
- Effective operational capacity of the balanced cells demonstrates a noticeable increase over the unbalanced cells
Future Work

- Integrate power dissipated to calculate joules used during balancing
- Show that joules dissipated and standard deviation flatten off as time increases
- Create a merit of efficiency by comparing the joules used during balancing to the increased operational capacity
- Full stack integration incorporating a master device
- Full system integration with the LPRDS system