Low-Maintenance Solar Power & Battery Management System for Remote Outdoor Devices

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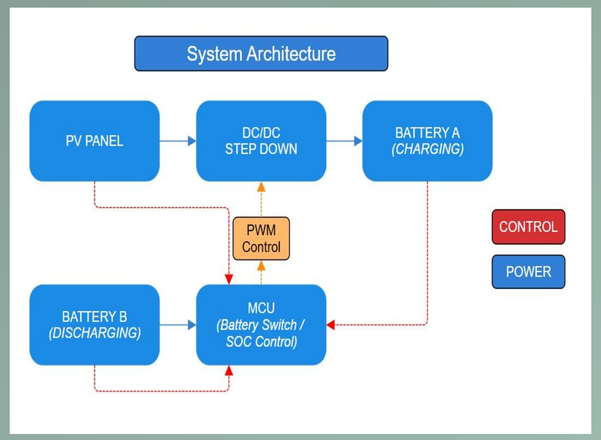
Objective

- Remote sensors lack reliable long-term power
- System must operate **without maintenance**
- Designed for **low-light, outdoor environments**
- Goal: **maximize energy harvesting + protect batteries**

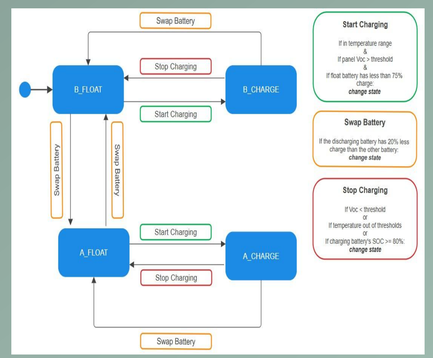
Overview



- System collects solar power as available
- MCU manages panel MPPT & Battery SOC
- MCU switches batteries between charge, discharge and float
- Enables long-term, maintenance-free operation of remote sensors
- Amorphous panels + $LiFePO_4$ chosen for robustness

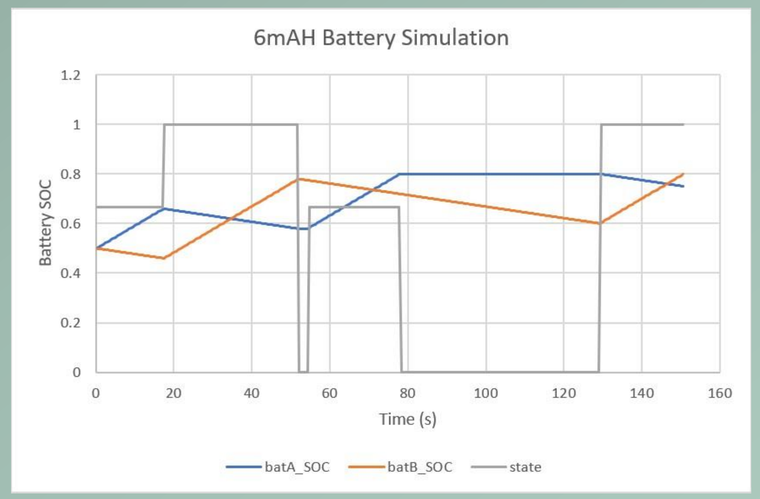
Approach/Results

Battery Management System



- Dual-battery system for continuous operation
- MCU switches batteries between charging and discharging
- State-Of-Charge (SOC) used to control transitions
- Prevents overcharge and deep discharge

Battery SOC and Switching Behavior

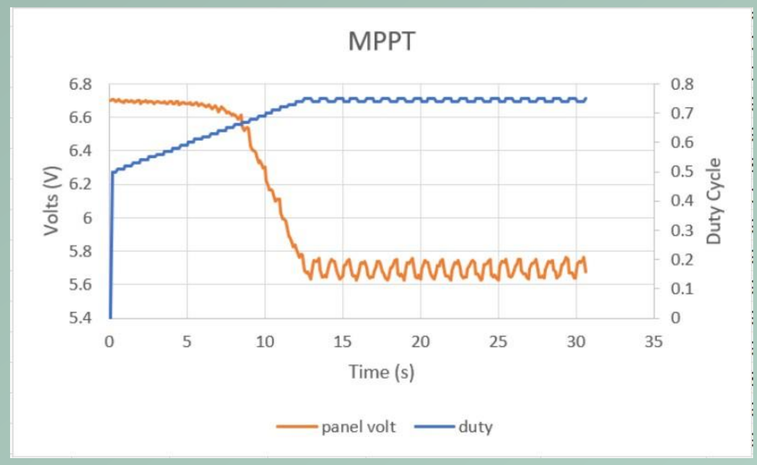


- Batteries alternate between charge, discharge and float based on SOC thresholds
- System maintains operation within safe charge limits (20-80%)
- Discreet state transitions demonstrate autonomous battery management

Approach/Results

MPPT Control (FOCV Method)

- Uses panel voltage to estimate maximum power point (V)
- Regulates operating voltage to ~85% of panel Voc
- Does not require current sensing
- Stable low and variable lighting conditions



- System converges to a stable operating point under load
- Small oscillations indicate active tracking near maximum power point

Conclusion

- Functional prototype successfully developed
- Enables long-term, maintenance free operation
- System adaptable to various outdoor applications

Future Work

- Hardware refinement (PCB + enclosure)
- Firmware Updates
- Long-term outdoor testing
- Optimization for specific deployment environments
- Integration with sensor network