Zhejiang University/University of Illinois Urbana-Champaign Institute
ECE445/ME470
Design Document
24V Smart Battery Charging System with Health Management

Team members：
Zhibo Zhang
Yanbo Chen
Yiwei Zhao
Hongda Wu

Instructor: Lin Qiu
TA: Shengwei Chen
Project No.29

13th April 2025

Contents

1. Introduction

Our team's design project, the "24V Intelligent Battery Charging System", addresses critical shortcomings in conventional battery charging technologies. Traditional systems suffer from inefficiencies such as low charging speeds, limited energy storage capacity, significant energy loss during charging, and insufficient battery health monitoring. Existing battery management systems lack comprehensive monitoring of key parameters (voltage, temperature, charge/discharge cycles, state of charge, etc.), leading to shortened battery lifespan, performance degradation, and poor user experience. Furthermore, in alignment with global carbon neutrality goals, integrating solar energy—a clean, renewable power source—into charging infrastructure has become imperative.

The system leverages solar panels to charge a 24V battery while continuously monitoring key metrics (voltage, current, power, and state of charge) through an embedded Battery Health Monitor. This functionality ensures efficient energy harvesting and proactive battery maintenance.

Green Energy Integration： Use solar panels as the primary power source to deliver clean and efficient power supply.

High-Efficiency Charging： Incorporate advanced power electronics and intelligent charging algorithms to achieve AC/DC conversion with minimal energy loss, significantly reducing charging time and improving efficiency.

Battery Health Management： Integrate a real-time health monitoring module to track critical parameters (voltage, current, temperature, state of charge) for optimal battery performance, extended lifespan, and enhanced safety.

Fault Detection & Protection： Implement automated fault detection (overvoltage, undervoltage, leakage current, internal short circuits) with instant circuit interruption to prevent component damage and ensure user safety.

Thermal Management： Deploy temperature-activated cooling systems to mitigate heat buildup during operation, maintaining battery health under high-load conditions.

1. Design

1.1 Diagrams

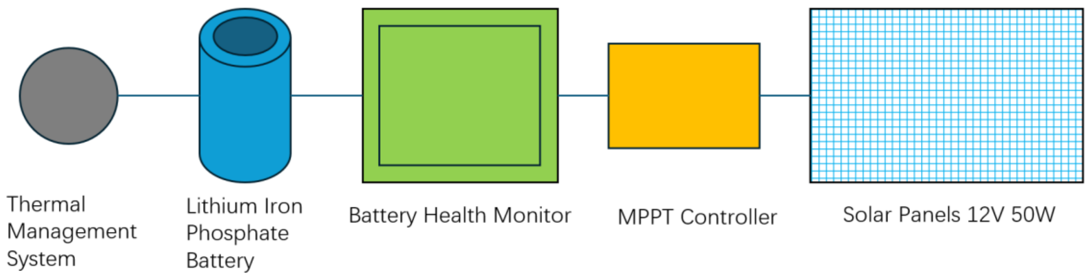

Figure 1: Concept diagram

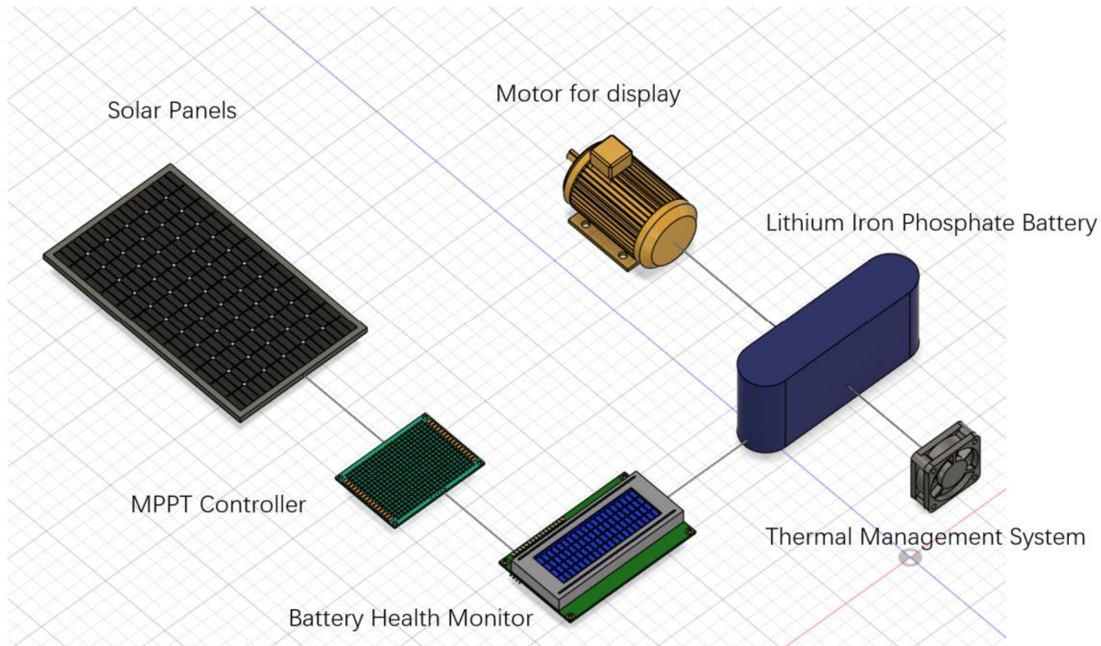

Figure 2: Schematic diagram of all components

1.2 Components

Solar Panels: Convert solar energy into electrical power to drive system operations and charge the battery.

MPPT Controller: A custom-designed PCB-based Maximum Power Point Tracking (MPPT) controller stabilizes variable solar panel outputs, ensuring consistent and optimal power delivery to the system.

Battery Health Monitor： A PCB-integrated monitoring module provides real-time tracking of battery parameters (current, voltage, state of charge, power) during charging/discharging cycles. And it contains a safety-critical circuit protection device that disconnects power upon detecting faults (undervoltage, overvoltage, leakage, short circuits).

Lithium Iron Phosphate Battery： High-capacity 12.8V, 6000mAh lithium-ion battery optimized for stable energy storage and longevity.

Thermal Management System： Temperature-sensitive cooling fans activate during overheating conditions to dissipate excess heat and maintain safe operating temperatures.

STM32: Serves as the central controller that acquires voltage and current signals and performs data processing. Then outputs the results to the display while also handling user input via buttons and communication through the serial interface.

1.3 Technical Highlights

Solar-Powered Sustainability: Reduces reliance on grid electricity while aligning with carbon-neutral initiatives.

Adaptive Charging Algorithms: Minimizes energy loss and maximizes charging efficiency.

User-Centric Monitoring: Real-time data visualization empowers users to optimize battery usage.

Proactive Safety Protocols: Multi-layered fault detection and thermal management ensure system reliability.

This system represents a holistic solution for modern energy challenges, combining renewable energy integration, intelligent charging, and robust battery stewardship.

3. Cost and schedule

3.1 Cost analysis

The following are estimates:

Solar Panels: 100 RMB.

Lithium Iron Phosphate Battery: 150 RMB.

MPPT Controller: Four weeks were spent on design, with a production cost of 300 RMB.

Battery Health Monitor: Six weeks were spent on design, with a production cost of 500 RMB.

Thermal Management System: Two weeks were spent on design, with a production cost of 100 RMB.

3.2 Schedule

We will complete the design and testing of each component in the next four weeks.

Week	Task	Member
2025.4.20	Design and test Solar panels and batteries.	Yiwei Zhao Hongda Wu
2025.4.27	Design and test MPPT and Battery Health Monitor.	Zhibo Zhang Yanbo Chen
2025.5.4	Test overall	Zhibo Zhang Yanbo Chen Yiwei Zhao Hongda Wu

4 Ethical Considerations and Safety Analysis

4.1 Ethical Considerations

This project adheres to the core principle of technology serving sustainable development and raises no ethical concerns, justified as follows:

1. Environmental Protection and Carbon Neutrality: The system relies on solar energy as its primary power source, reducing dependence on fossil fuels and directly supporting global carbon neutrality goals, aligning with green technology ethics.

2. Fairness and Accessibility: By improving charging efficiency and battery lifespan, the system lowers long-term user costs, particularly benefiting resource-constrained regions (e.g., remote areas or environments without stable grids), thereby promoting equitable energy access.

3. Data Transparency and User Rights: The system monitors only battery physical parameters (e.g., voltage, temperature, state of charge) and does not collect user privacy data. All functionalities are designed to extend battery life and optimize user experience, eliminating risks of technological misuse.

4. Resource Sustainability: By minimizing energy waste and reducing battery replacement frequency, the system alleviates the consumption of rare metal resources in battery production, indirectly lowering the of the supply chain.

4.2 Safety Analysis

The system incorporates multiple hardware and software safeguards, posing minimal safety risks, with specific measures including:

1. Real-Time Monitoring and Fault Protection: The embedded battery health monitor tracks voltage, current, temperature, and other parameters in real time. Upon detecting abnormalities such as overvoltage, overcurrent, or overheating, it immediately triggers circuit-breaking protection to prevent thermal runaway or explosion risks.

2. Intelligent Charge/Discharge Management: Adaptive charging algorithms dynamically adjust charging power based on battery status, preventing damage or hazards caused by overcharging or over-discharging.

3. Hardware Isolation Design: Physical isolation layers (e.g., optocouplers) are implemented between the solar input circuit and the battery system to protect against lightning strikes or voltage surges.

4. Protection Standards and Material Safety: Critical components (e.g., battery interfaces, circuit boards) use fire-resistant and short-circuit-proof materials, compliant with IP54-rated enclosures to ensure stable operation in humid or dusty environments.

5. User Alerts and Emergency Mechanisms: Audible and visual alarms notify users of abnormal conditions, while a manual emergency stop switch provides additional operational safety.

References

[1] Wu, T. Z., Li, Y. A., & Peng, H. G. (2025). Remaining useful life prediction of lithium-ion batteries based on charge-discharge characteristics and surface temperature variations. Journal of Electronic Devices, 48(1), 123–129.

[2] Zhou, D. B., Yang, L., Liu, D. P., et al. (2023). Experimental study on thermal management of lithium batteries during cyclic charge-discharge processes. Journal of Chemical Engineering of Chinese Universities, 37(4), 552–559.

[3] Yang, N. (2022). Data-driven health state assessment of lithium-ion batteries [Master's thesis, South China University of Technology]. China Academic Journals Electronic Publishing House. DOI: 10.27151/d.cnki.ghnlu.2022.003727

[4] Guan, W. R. (2020). Application of electrical automation in solar photovoltaic power generation. Encyclopedia Forum Electronic Magazine, 2020(7), 1480.