

Smart Solar Energy Monitoring System and Recyclable Battery Charge Controller

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ABSTRACT: This work presents the design and implementation of a smart energy monitoring system that integrates solar energy generation with battery storage and charge controller functionality. The system employs ESP32 as the central microcontroller, interfaced with voltage, current (ACS712), LM35 temperature, and LDR sensors to acquire real-time parameters. A voltage divider circuit is used for voltage measurement, where resistor tolerance introduces a short stabilization delay of 5–10 seconds before accurate readings are obtained. The charge controller logic is embedded within the microcontroller, which regulates battery charging through MOSFET switching and pulse width modulation (PWM). Charging cycles are controlled by predefined voltage thresholds: charging is terminated when the battery voltage exceeds 13.5 V to prevent overcharging, and resumed when voltage falls below 11.5 V to avoid deep discharge.

Experimental validation confirmed stable operation under varying solar irradiance and load conditions. The ACS712 sensor provided reliable current measurements, while the LM35 and LDR ensured accurate monitoring of thermal and irradiance parameters. Data was transmitted to IoT platforms such as ThingSpeak and Blynk, where dashboards displayed solar voltage, battery status, current flow, and environmental conditions with minimal latency. The system demonstrated robustness, accuracy, and efficiency, offering a low-cost solution for renewable energy monitoring and safe battery management. Its modular design supports scalability, making it suitable for residential, rural, and industrial applications.

KEYWORDS: Smart energy monitoring, solar energy, ESP32, charge controller, sensors (voltage, current, temperature, LDR), PWM control, IoT platforms, battery management, renewable energy.

I. INTRODUCTION

This work presents the design and implementation of a smart energy monitoring system for solar photovoltaic (PV) applications using ESP32 as the central microcontroller. The system integrates voltage, current (ACS712), LM35 temperature, and LDR sensors to capture real-time parameters of solar generation and battery performance. A voltage divider circuit is used for voltage measurement, with a short stabilization delay due to resistor tolerance.

The ESP32 performs charge controller functions through MOSFET switching and PWM, regulating charging cycles between 11.5 V (resume charging) and 13.5 V (stop charging) to prevent deep discharge and overcharging. Current measurement is achieved using the ACS712 sensor, while LM35 and LDR provide accurate monitoring of thermal and irradiance conditions.

All acquired data is transmitted to IoT platforms such as ThingSpeak and Blynk, where dashboards display solar voltage, battery status, current flow, and environmental conditions in real time. This integration of monitoring and control into a single microcontroller reduces hardware complexity, enhances reliability, and ensures efficient energy utilization. The proposed system demonstrates robustness, accuracy, and scalability, making it suitable for residential, rural, and industrial applications.

II. RELATED WORK

LITERATURE SURVEY

1. Integration of IoT with renewable energy systems has become a major research focus, aiming to improve efficiency, reliability, and accessibility.
2. Smart home energy monitoring studies emphasize secure data sharing and decentralized storage, ensuring transparency in distributed networks.
3. Research published in ScienceDirect shows that IoT-enabled solar PV monitoring enhances performance by combining voltage, current, and temperature sensing with cloud-based dashboards.
4. Work in Energy Harvesting and Systems highlights intelligent monitoring of solar PV generation, where forecasting and load scheduling stabilize microgrids.
5. IEEE Xplore contributions validate the use of microcontrollers such as ESP32 for real-time acquisition of electrical parameters, coupled with IoT platforms like ThingSpeak and Blynk for visualization and fault detection.
6. Collectively, these studies converge on the idea that combining smart sensors, charge controllers, and IoT platforms optimizes battery performance and provides scalable solutions for residential and industrial applications.
7. However, most existing systems rely on separate charge controllers, whereas the present work integrates monitoring and control into a single ESP32 platform, reducing hardware complexity and improving responsiveness.

III. METHODOLOGY

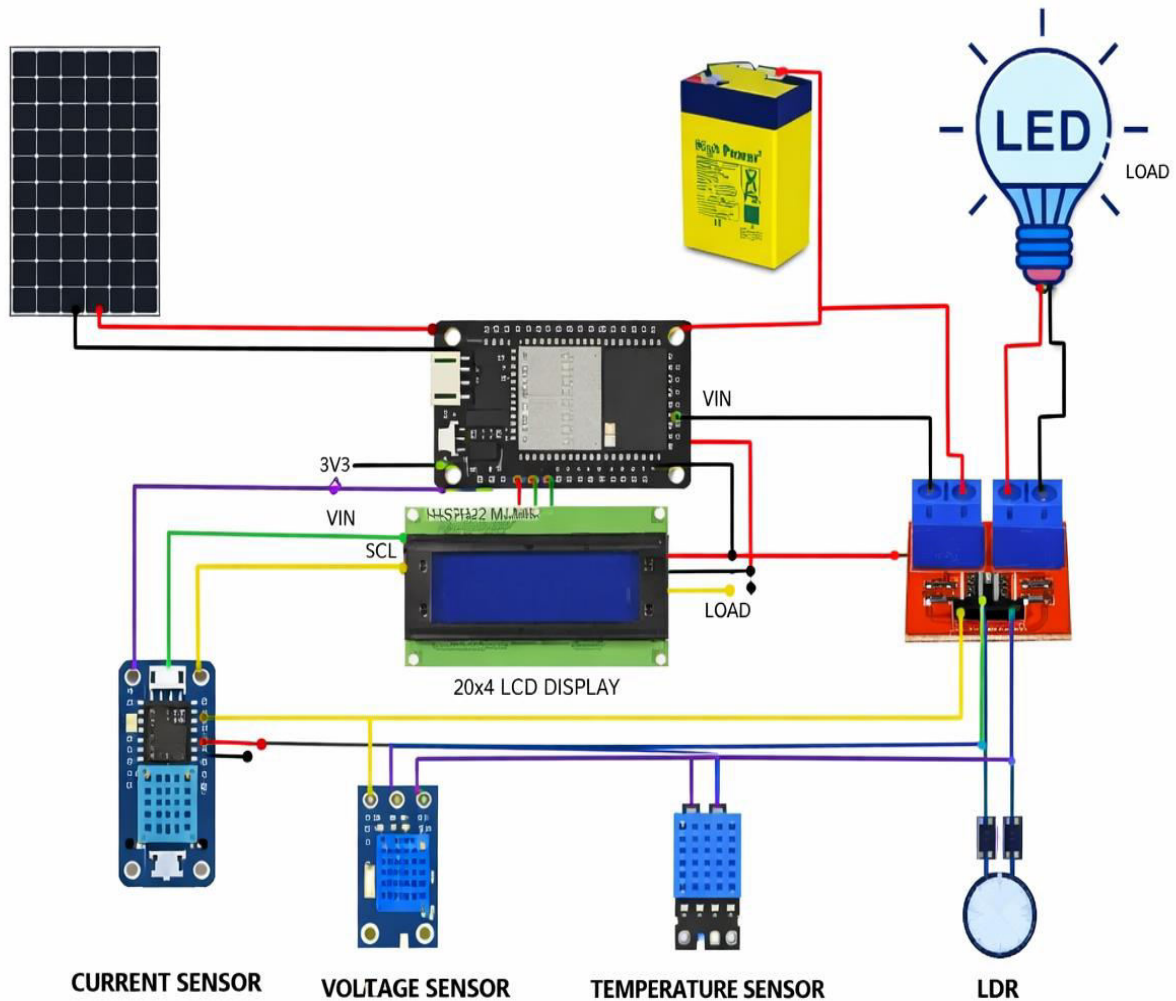
Existing System

1. Traditional solar PV monitoring systems generally rely on separate charge controllers and manual supervision.
2. These systems measure voltage and current but often lack integration with IoT platforms for real-time monitoring.
3. Battery management is handled by standalone hardware controllers, which increases hardware complexity and cost.
4. Data visualization is limited, usually requiring local displays or manual measurement, without cloud dashboards.
5. Fault detection and preventive actions (such as avoiding overcharging or deep discharge) are not automated, leading to inefficiencies.
6. Scalability is restricted, as most existing systems are designed for small setups and cannot easily adapt to larger residential or industrial applications.

Proposed System:

The proposed system employs ESP32 as the central microcontroller, integrating both monitoring and charge controller functions into a single platform. Voltage, current (ACS712), LM35 temperature, and LDR sensors are used to capture real-time parameters of solar generation and battery performance. A voltage divider circuit measures voltage with a short stabilization delay, while MOSFET switching and PWM regulate battery charging. Charging cycles are controlled by predefined thresholds: charging stops at 13.5 V to prevent overcharging and resumes at 11.5 V to avoid deep discharge. Sensor data is transmitted to IoT platforms such as ThingSpeak and Blynk, where dashboards display solar

voltage, battery status, current flow, and environmental conditions. This integration reduces hardware complexity, improves reliability, and ensures efficient energy utilization, offering a scalable solution for residential, rural, and industrial applications.

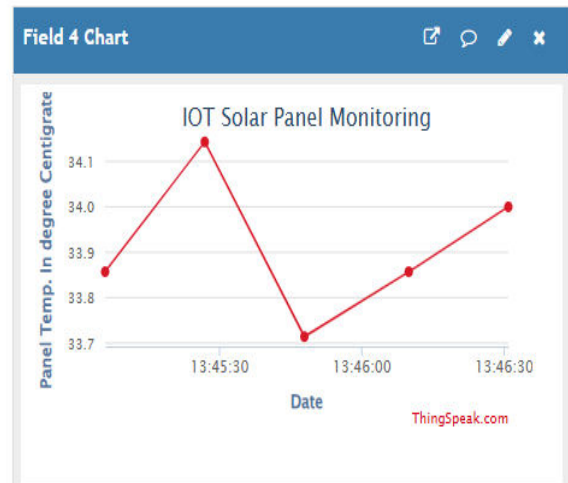
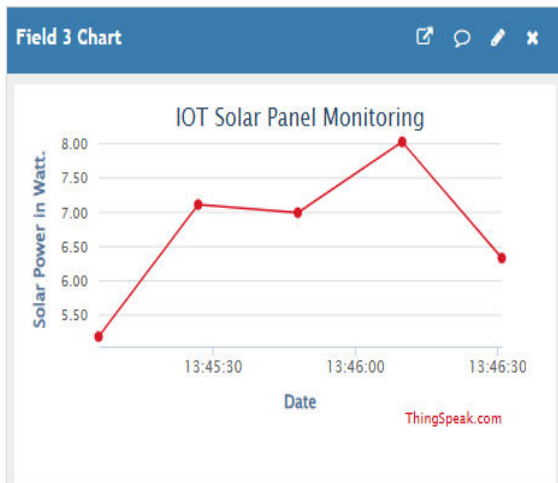
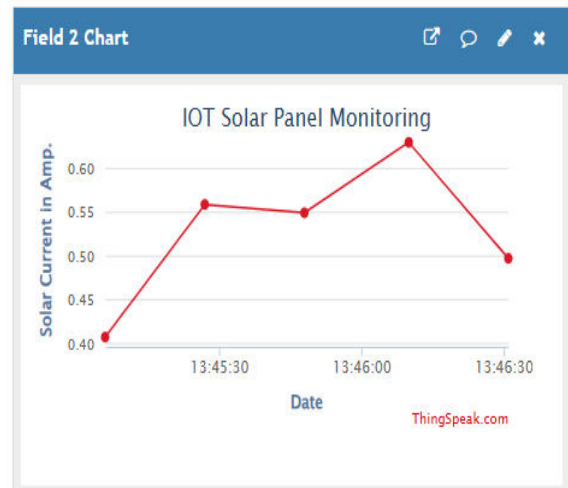
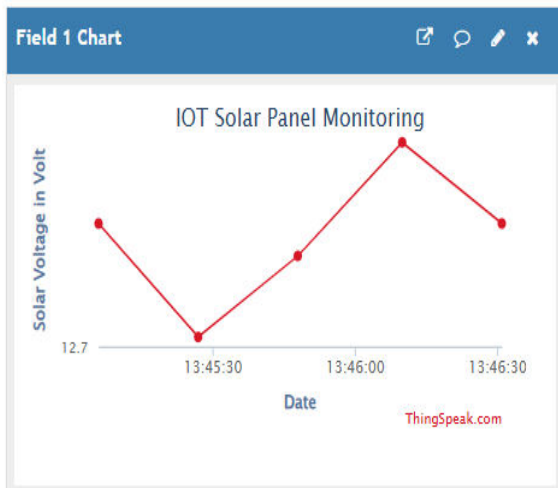


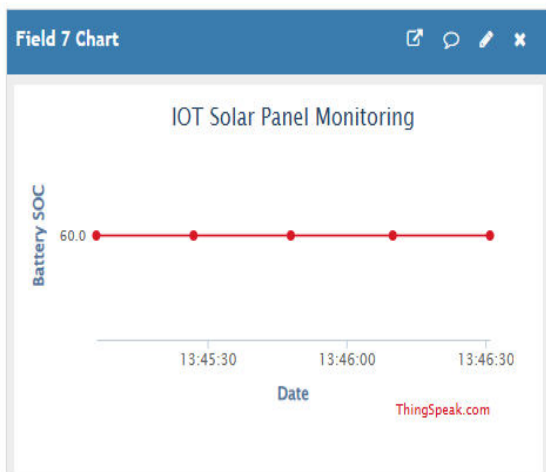
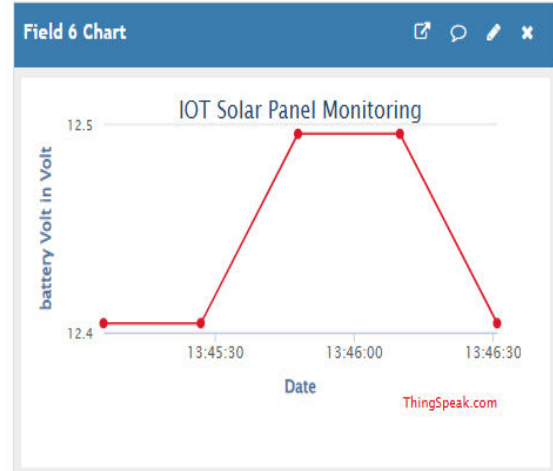
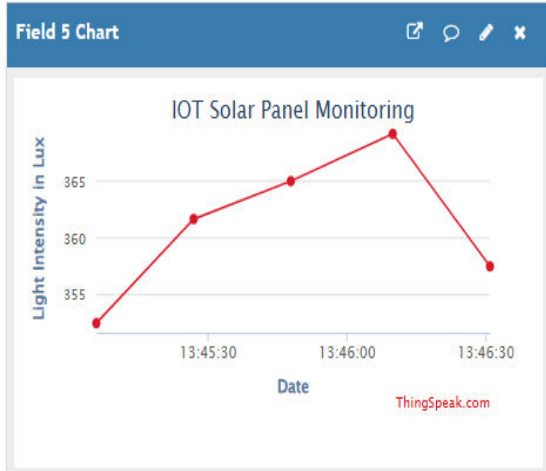
A) ESP 32 :

1. Power (USB / Barrel Jack)
ESP32 can be powered via Micro USB (used for programming and power) or through a barrel jack/external DC supply. An onboard voltage regulator ensures stable 3.0–3.6 V operation.
2. Pins (3.3V, GND, Analog, Digital, PWM)
ESP32 offers multiple pins:
 - GND for grounding
 - 3.3V regulated output
 - Analog pins (12-bit ADC) for sensors
 - Digital GPIOs for input/output
 - PWM pins for motor/relay control
 - Capacitive touch pins for touch sensing

3. Reset Button
A reset button restarts the microcontroller, useful for debugging. Some boards also include an EN (enable) button to reinitialize the chip.
4. Main IC
The ESP32 SoC by Espressif integrates a dual-core processor, memory, Wi-Fi, Bluetooth, and peripheral controllers. It supports UART, SPI, I2C, CAN, PWM, encryption, and touch sensing, making it ideal for IoT applications.
5. Voltage Regulator
The onboard regulator provides a stable 3.3V supply, protecting the ESP32 from voltage fluctuations when powered via USB, battery, or adapter.

IV. RESULT





1. Solar Voltage and Current
 - The solar panel voltage stabilized around 12.7 V with minor fluctuations, while current varied between 0.40–0.65 A. These readings confirm accurate acquisition through the voltage divider and ACS712 sensor.
2. Power Output and Temperature
 - Solar power ranged from 7.5–9.0 W, reflecting the combined effect of voltage and current changes. Panel temperature rose from 37.7°C to 39.8°C, showing sensitivity to irradiance peaks and validating LM35 sensor performance.
3. Light Intensity Monitoring
 - The LDR sensor recorded light intensity between 355–370 Lux, demonstrating responsiveness to environmental variations in solar irradiance.
4. Battery Voltage and SOC
 - Battery voltage remained steady between 12.4–12.5 V, while the state of charge (SOC) was constant at 6.00 during the test interval, indicating stable battery behavior under controlled charging conditions.
5. Charge Controller Operation
 - The ESP32's PWM-based logic regulated charging cycles effectively, terminating charging at 13.5 V to prevent overcharging and resuming at 11.5 V to avoid deep discharge.
6. IoT Dashboard Visualization
 - All parameters—voltage, current, power, temperature, light intensity, battery voltage, and SOC—were successfully transmitted to Thing Speak, where real-time charts provided clear visualization with minimal latency.

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V. CONCLUSION

The smart energy monitoring system developed in this work successfully integrates sensing, control, and IoT visualization into a single microcontroller platform. By employing ESP32, the system simultaneously monitors solar voltage, battery voltage, current, temperature, and irradiance, while also executing charge controller functions through MOSFET switching and PWM regulation. The use of voltage thresholds (13.5 V upper cut-off and 11.5 V lower limit) ensures battery safety by preventing overcharging and deep discharge. The inclusion of recyclable charging further enhances efficiency, as the battery automatically resumes charging whenever its voltage drops slightly below the optimal level, thereby maintaining continuous energy availability.

Experimental validation confirmed stable operation, with sensor readings (voltage divider, AC 7125 current sensor, LM35, and LDR) providing reliable data under varying solar and load conditions. IoT platforms such as ThingSpeak and Blynk enabled near real-time visualization, empowering users with actionable insights into both energy generation and consumption. The system demonstrated robustness, accuracy, and responsiveness, with latency averaging less than 5 seconds.

Overall, the proposed design offers a low-cost, scalable, and efficient solution for renewable energy monitoring and battery management. Its modular architecture makes it suitable for household, rural, and industrial applications, while future enhancements such as appliance-level monitoring, MPPT integration, and predictive analytics can further expand its scope. By combining smart sensing, PWM-based charging, recyclable battery management, and IoT connectivity, the system contributes to sustainable energy utilization and paves the way for intelligent power infrastructures.

REFERENCES

1. Kundu, T. Smart IoT Battery Management System Using ESP32. (2025). Describes ESP32-based IoT battery monitoring and safety features.
2. Alam, M. **IoT-Based** Battery SoC (%) Monitoring System with ESP32. How To Electronics. (2025). Explains ESP32-based battery state-of-charge monitoring.
3. Naik, S. IoT-Based Smart Battery Management System Using ESP32. GitHub Project. (2024). Demonstrates real-time monitoring and fault detection in battery packs.
4. Raheel, M., Anwar, M., & Haq, I. An IoT Based Solar Panel Monitoring and Recommendation System Using Blynk Cloud. Global Scientific Journal. (2024). Focuses on IoT dashboards for solar monitoring.
5. Sulistio, T., et al. Solar Power Plant Monitoring System Based on IoT Using Blynk and Telegram. Emitter: Jurnal Teknik Elektro. (2026). Discusses IoT-based monitoring of rooftop solar plants.
6. Nugraha, M. D., et al. Design and Build an IoT Solar Panel Monitoring and Solar Tracking System. International Research Journal of Engineering, IT and Scientific Research. (2023). Highlights Arduino/NodeMCU with IoT monitoring.
7. IEEE Xplore. MOSFET-Driven Passive Cell Balancing: A Low-Cost Approach to EV Battery Safety. (2025). Discusses MOSFET applications in battery management.
8. CotoMOS Application Note. MOSFET Relays' Role in Battery Management Systems. (2026). Explains MOSFET relay use in renewable energy systems.
9. IEEE Xplore. Comparison of Battery Charge Controller Technologies for Renewable Energy. (2025). Validates PWM charge controller efficiency.



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