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Development Of Smart Battery Monitoring & Control System For Electric Vehicle Using IOT

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ABSTRACT : The rapid growth of electric vehicles has increased the importance of efficient battery monitoring and management systems. Batteries are the primary energy source in electric vehicles, and improper battery management can reduce battery lifespan and create safety issues such as overheating, overcharging, and excessive current flow. A Battery Management System (BMS) is used to monitor and protect batteries by continuously checking important parameters such as voltage, current, and temperature.This research paper presents the design and implementation of an IoT-Based Battery Management System for electric vehicles. The proposed system uses ESP32/Arduino as the main controller along with voltage sensors, current sensors, and temperature sensors for continuous battery monitoring. The collected data is transmitted to cloud platforms such as Thing Speak or Blynk using Wi-Fi communication, enabling real-time remote monitoring through smartphones or computers.

The project was implemented in two phases. During the first phase, hardware integration and programming were completed, but stable output was not achieved due to communication and sensor-related issues. In the second phase, troubleshooting, debugging, sensor calibration, and software optimization were performed to improve system performance and reliability.

INDEX TERMS : Battery Management System, Internet of Things, Electric Vehicle, ESP32, Sensors, Real-Time Monitoring, Cloud Platform.

1.Introduction

1.1 Background

Electric vehicles (EVs) are becoming increasingly popular because they help reduce pollution and dependence on fossil fuels. Batteries are the main power source of electric vehicles, and their performance directly affects vehicle efficiency, driving range, and safety. Therefore, proper battery monitoring and management are very important. A Battery Management System (BMS) is used to monitor important battery parameters such as voltage, current, and temperature. Traditional battery monitoring systems have limited features and often require manual supervision. To overcome these limitations, Internet of Things (IoT) technology can be integrated with BMS for real-time monitoring and remote accessibility. The IoT-Based Battery Management System allows users to monitor battery conditions remotely through smartphones or computers. It also improves battery safety by generating warning alerts during abnormal conditions such as overheating, excessive current flow, and over-voltage.

1.2 Need for the Project

As the use of electric vehicles increases, efficient battery monitoring systems have become essential. Improper battery management may lead to battery failure, overheating, reduced battery lifespan, and safety risks. Traditional systems often fail to provide continuous monitoring and remote access to battery data.

The need for this project arises from the requirement for a smart, reliable, and low-cost battery monitoring system that can provide real-time battery information. By integrating IoT technology with battery monitoring, users can access battery data from anywhere through internet connectivity.

1.3 Overview of the Proposed System

The proposed system is an IoT-Based Battery Management System designed for monitoring battery voltage, current, and temperature continuously. The system uses sensors connected to an ESP32/Arduino microcontroller for collecting battery data.

The voltage sensor measures battery voltage, the current sensor measures charging and discharging current, and the temperature sensor monitors battery temperature. The ESP32 processes the sensor data and transmits it to cloud platforms such as ThingSpeak or Blynk using Wi-Fi communication [1-14].

2. Literature Review

1.Traditional Battery Management Systems Lietrature Review

Traditional Battery Management Systems (BMS) were mainly used for monitoring basic battery parameters such as voltage and current. These systems required manual supervision and had limited monitoring capabilities. They were unable to provide remote accessibility and real-time monitoring. Due to the lack of advanced communication technologies, fault detection and battery analysis were slow and less efficient. These limitations created the need for smart battery monitoring systems with improved safety and monitoring features.

2. IoT-Based Battery Monitoring Systems

With the advancement of Internet of Things (IoT) technology, researchers developed smart Battery Management Systems capable of real-time monitoring and remote accessibility. IoT-based systems use sensors, microcontrollers, and cloud platforms to monitor battery conditions continuously. The collected data is transmitted to cloud platforms such as ThingSpeak or Blynk using Wi-Fi communication. Users can monitor battery performance remotely through smartphones or computers. These systems improve monitoring efficiency, reduce manual work, and provide warning alerts during abnormal battery conditions.

3. Sensors and Microcontrollers Used in BMS

Researchers widely use microcontrollers such as Arduino, ESP32, NodeMCU, and Raspberry Pi for implementing Battery Management Systems. These controllers process sensor data and manage IoT communication. Different sensors are used for monitoring battery conditions:

Voltage sensors for voltage measurement

Current sensors for current monitoring

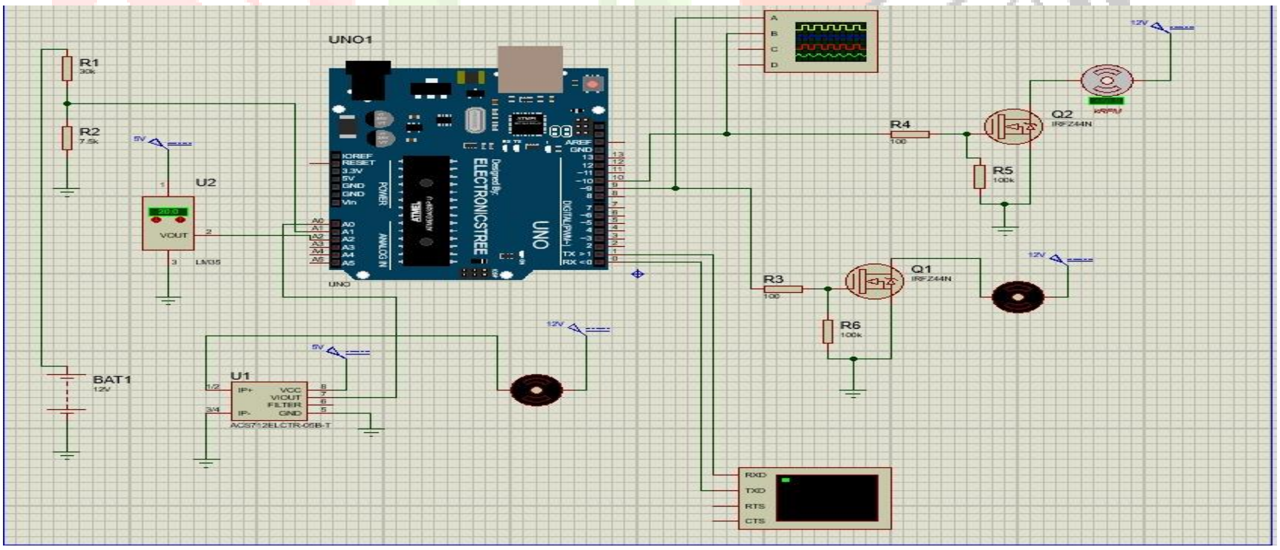
Temperature sensors for thermal monitoring

ESP32 is commonly preferred because it provides built-in Wi-Fi communication, low power consumption, and efficient processing capability. Proper sensor integration improves monitoring accuracy and battery safety.

4. Limitations and Research Gap

Although many IoT-Based Battery Management Systems have been developed, several challenges still exist. Many systems face issues such as sensor inaccuracies, unstable communication, internet dependency, and hardware integration problems. Low-cost systems often experience communication delays and unstable monitoring performance. There is still a need for a reliable, accurate, and affordable Battery Management System capable of stable real-time monitoring and efficient IoT communication. The proposed project focuses on solving these issues by improving hardware integration, sensor accuracy, and cloud communication reliability.

3. Circuit Configuration



The circuit configuration of the proposed IoT-based Battery Management System is built around the Arduino Uno microcontroller, which serves as the central controller for the entire setup. The circuit consists of sensing, control, and protection sections that work together to monitor the battery parameters and manage charging and discharging safely. The main components used are a 12 V battery source, voltage divider network, ACS712 current sensor, LM35 temperature sensor, IRFZ44N MOSFETs for switching, and an IoT communication module for data transmission.

The battery section uses a 12 V DC battery (BAT1) as the main power source. The battery voltage is monitored through a voltage divider circuit composed of two resistors (R1 = 30 kΩ and R2 = 7.5 kΩ). This divider reduces the high battery voltage to a safe level (below 5 V) suitable for the Arduino's analog input pin (A0). The measured analog voltage is later scaled in software to display the actual battery voltage.

The current sensing section employs an ACS712 current sensor (U1). This sensor measures both charging and discharging currents by detecting the magnetic field around the current-carrying conductor. The sensor provides an analog voltage proportional to the current flow, which is fed into the Arduino's analog input pin (A1). This allows continuous monitoring of the current to identify charging/discharging conditions and protect against overcurrent.

For temperature monitoring, an LM35 temperature sensor (U2) is connected to analog pin A2 of the Arduino. The LM35 produces a linear output of 10 mV per °C, which is used to monitor the battery temperature in real time. When the temperature exceeds a predefined safe limit (typically 45 °C), the controller initiates protective actions.

The control section uses two N-channel MOSFETs (Q1 and Q2, both IRFZ44N) as electronic switches. Q1 controls the load connection (discharging), and Q2 controls the charging circuit. Each MOSFET is driven by a digital output pin of the Arduino through gate resistors (R3 and R4 = 10 Ω) and pull-down resistors (R5 and R6 = 10 kΩ) to ensure proper switching. When the Arduino detects overvoltage, undervoltage, or overheating, it immediately switches off the corresponding MOSFET to isolate the battery.

An alarm buzzer is connected to provide an audible indication during fault conditions such as overtemperature or overvoltage. The circuit also includes an IoT module (ESP8266 or equivalent) connected via the serial interface (TX/RX pins) of the Arduino. This module uploads the monitored voltage, current, and temperature data to an online IoT platform such as Thing Speak or Blynk, enabling remote monitoring and analysis.

The proposed IoT-based Battery Management System (BMS) for an electric vehicle operates in four distinct modes depending on the battery's electrical and thermal conditions. In the **Charging Mode**, the BMS becomes active when an external charger is connected and the battery voltage is below the full-charge threshold of approximately 14.2 V. During this mode, the system continuously measures the battery voltage through the resistive divider network, the charging current using the ACS712 Hall-effect sensor, and the temperature using the DHT11/LM35 sensor. The microcontroller supervises all parameters and terminates charging if the voltage exceeds 14.2 V, the current falls below the float-charge region, or the temperature exceeds 45 °C. Simultaneously, real-time data is transmitted to the IoT platform for monitoring.

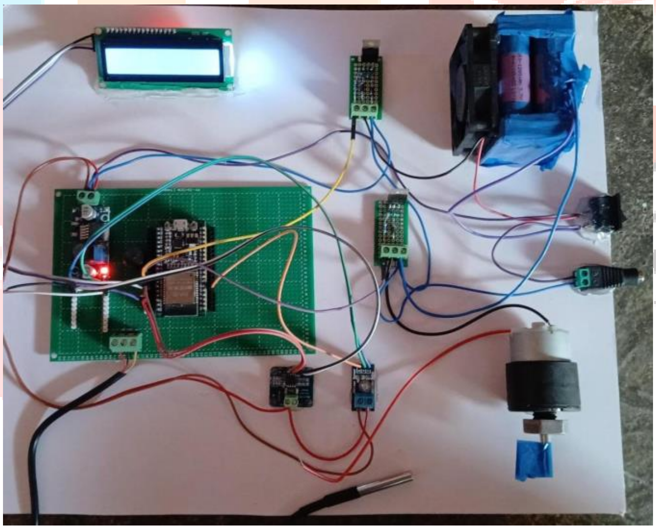
In the **Discharging Mode**, the battery supplies power to the motor or load, and the BMS monitors dynamic performance under load. The voltage, discharge current, and temperature are continuously tracked to estimate the State-of-Charge (SOC) and to identify abnormal conditions such as deep discharge (voltage below 10.5 V), excessive current draw beyond the sensor limit, or thermal rise due to heavy load. Whenever unsafe values are detected, the controller initiates protective action and sends fault notifications via the IoT module. This mode ensures operational safety during vehicle motion.

The system enters **Idle or Standby Mode** when no charging source or load is connected to the battery. In this mode, the BMS remains powered but operates in a low-energy state, periodically sampling the open-circuit voltage to evaluate the natural self-discharge rate of the battery. Minimal sensing activity is maintained to conserve power, while essential parameters are still updated on the IoT dashboard to track battery health during non-operational periods.

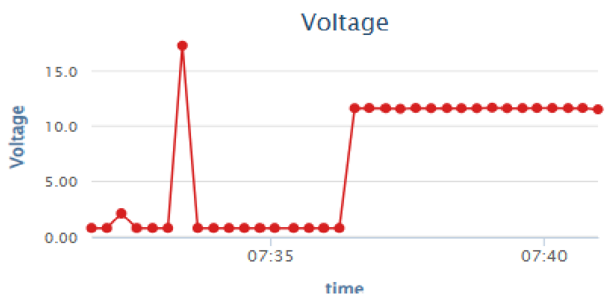
Finally, the **Fault or Protection Mode** is activated whenever any measured parameter exceeds predefined safety limits. This includes over-voltage, under-voltage, over-current, over-temperature, or sensor malfunction. When a fault is detected, the BMS immediately disconnects the battery using a protection relay or MOSFET switch to prevent thermal runaway or irreversible battery damage. A fault message is logged, and an alert is transmitted to the IoT interface to inform the user. This mode ensures robust protection and enhances the reliability of the electric vehicle battery system.

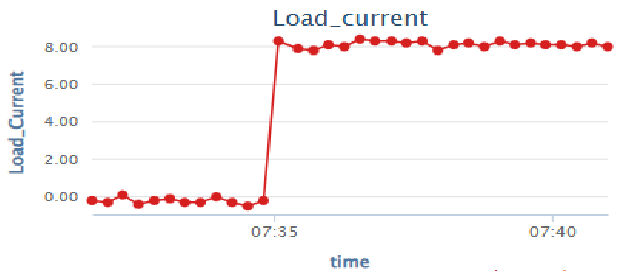
Overall, the circuit configuration ensures efficient sensing, protection, and communication between the battery, controller, and user. The use of simple components and clear modular design makes the system easy to simulate, implement, and expand for higher-voltage electric vehicle applications.

4. Proposed System



5. Output Waveform From Thing Speak Software

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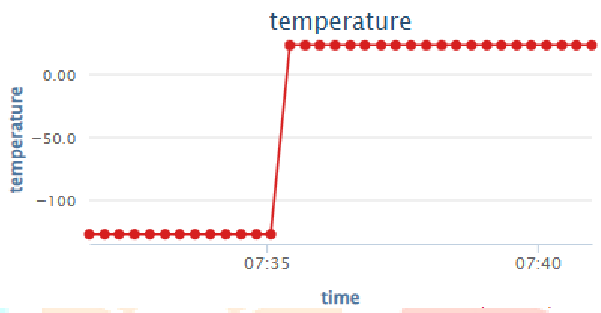
time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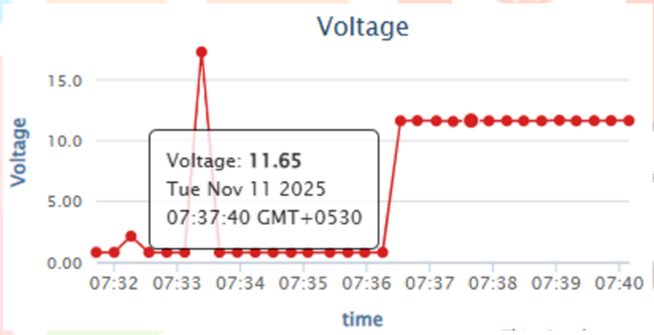
time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0.00
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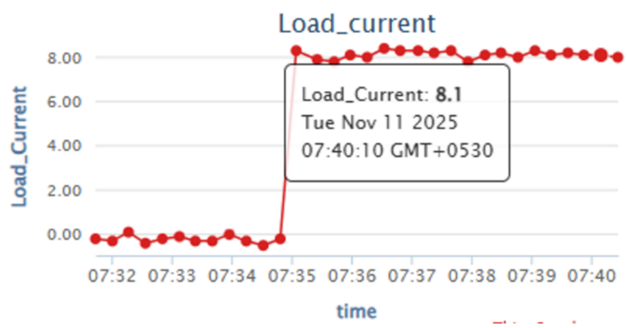
time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07:32 07:33 07:34 07:35 07:36 07:37 07:38 07:39 07:40
time

6. Future Scope and Direction

1. State of Charge (SOC) and State of Health (SOH) Monitoring : Future improvements in the IoT-Based Battery Management System can include advanced battery analysis features such as State of Charge (SOC) and State of Health (SOH) monitoring. SOC estimation helps determine the exact charging level of the battery, while SOH monitoring helps analyze battery condition, aging, and overall performance.

2. Artificial Intelligence and Machine Learning IntegrationArtificial : Intelligence (AI) and Machine Learning (ML) technologies can be integrated into the Battery Management System for smart battery analysis and fault prediction. AI-based systems can analyze battery behavior, detect abnormal conditions automatically, and predict battery failures before they occur.

3. Mobile Application and Advanced Alert System: In the future, a dedicated mobile application can be developed for easier battery monitoring and control. The mobile application can provide real-time battery status, graphical analysis, and warning notifications directly to users. Advanced alert systems using SMS, email, and push notifications can also be implemented to improve battery safety.

4. Renewable Energy and Wireless Charging Integration: Future Battery Management Systems can be integrated with renewable energy systems such as solar-powered charging systems. Solar integration can improve energy efficiency and support environmentally friendly transportation systems.

5. Industrial-Level Implementation and Smart Energy Management : The developed system can be further upgraded for industrial and commercial electric vehicle applications. Industrial-grade sensors, advanced communication protocols, and secure cloud platforms can improve system accuracy, reliability, and performance. Smart energy management techniques can also be implemented to optimize battery usage and power distribution automatically.

Conclusion

The proposed IoT-based Battery Management System (BMS) for electric vehicles provides an efficient and reliable solution for real-time monitoring and protection of lithium-ion battery packs. The integration of sensors with the Arduino Uno enables accurate measurement of key parameters such as voltage, current, and temperature, while the use of IoT technology ensures continuous data accessibility and remote supervision. The system automatically controls charging and discharging through MOSFET switches, effectively preventing overcharging, deep discharge, and overheating. The experimental and simulation results confirm that the developed BMS enhances battery safety, performance, and operational lifespan. The inclusion of IoT-based data logging helps analyze battery behavior under various conditions, enabling predictive maintenance and optimization of energy usage. Overall, this smart and low-cost design demonstrates great potential for practical implementation in modern electric vehicles and other renewable energy storage systems.

Reference

[1] H. He, R. Xiong, and J. Fan, "Evaluation of Lithium-Ion Battery Equivalent Circuit Models for State of Charge Estimation by an Experimental Approach," Energies, Vol. 4, No. 4, pp. 582–598, 2011.

[2] M. A. Hannan, M. M. Hoque, A. Mohamed, and A. Ayob, "Review of Energy Storage Systems for Electric Vehicle Applications: Issues and Challenges," Renewable and Sustainable Energy Reviews, Vol. 69, pp. 771–789, 2017.

[3] X. Hu, S. Li, and H. Peng, "A Comparative Study of Equivalent Circuit Models for Li-Ion Batteries," Journal of Power Sources, Vol. 198, pp. 359–367, 2012.

[4]. Malvekar, Sachin A., C. L. Bhattar, and Viraj B. Savakhande. "Non-Isolated High Voltage Gain DC DC Converters using Inductors for DC Microgrid." In 2018 International Conference on Control, Power, Communication and Computing Technologies (ICCPCCT), pp. 455-459. IEEE, 2018.

[5]. Kapse, Mrunal M., Nilofar R. Patel, Shruti K. Narayankar, Sachin A. Malvekar, and Kazi Kutubuddin Sayyad Liyakat. "Smart grid technology." International Journal of Information Technology and Computer Engineering 2, no. 6 (2022): 10-17.

[6]. Bhosale, Swaroopa S., Y. N. Bhosale, Uma M. Chavan, and Sachin A. Malvekar. "Power quality improvement by using UPQC: A review." In 2018 International conference on control, power, communication and computing technologies (ICCPCCT), pp. 375-380. IEEE, 2018.

[7]. Malvekar, Sachin A., and C. L. Bhattar. "Non-isolated High Voltage Gain Dcâ€“dc Converters Using Inductors For Pv Application." JournalNX (2018): 158-161.

[8]. Mahananda N. Pukale, Manisha K. Raichurkar, Shivani S. Aousekar, Nikita S. Rapelli, Prof. Sachin A. Malvekar, "IoT Based Smart Energy Meter", International Journal of Advanced Research in Science, Communication and Technology, pp.350, 2024.

[9]. Parshetti, Miss. Rutuja., Burbure, Miss. Shruti, Chavan, Miss. Shrutika, Tamshetti, Miss. Vijayalaxmi, Jagzap, Miss. Pradnya and Malvekar S. A. "Firefighting Robot: A Review." International Journal for Research in Applied Science and Engineering Technology 12, no. 12 (December 31, 2024): 2055–62.

[10]. Kasturi Ramesh Parbalkar, Rajlaxmi Vishwanath Yeldi, Ishwari Shakesh Jadhav, Krushanaveni Laxminarayan Sidral, Sachin A. Malvekar, "innovation to Industry: Roadblocks in Perovskite Solar Cell Commercialization", JNRID - Journal of Novel Research and Innovative Development (www.JNRID.org), ISSN:2984 8687, Vol.3, Issue 3, page no. a96-a101, March-2025.

[11]. Dindure, Dhanashri, Vaishnavi Mithapalli, Shivranjani Battul, S. A. Malvekar, and S. P. Patil. "Self-Operating Rain Detection System." International Journal of Innovative Science and Research Technology 10, no. 3 (2025): 2799-2803.

[12]. Priyanka Malyal, Bhargavi Konda, Maheshwari Kota, S. A. Malvekar "A photovoltaic solar system with multiple tasks," IJIREEICE, vol. 13, no. 4, Apr. 2025: 229-234.

[13] R. Xiong, F. Sun, H. He, and M. Ouyang, "A Data-Driven Multi-Scale Extended Kalman Filtering Based Parameter and State Estimation Approach of Lithium-Ion Battery in Electric Vehicles," Applied Energy, Vol. 113, pp. 463–476, 2014.

[14] M. Einhorn, F. Conte, C. Kral, and J. Fleig, "Comparison, Selection, and Parameterization of Electrical Battery Models for Automotive Applications," IEEE Transactions on Power Electronics, Vol. 28, No. 3, pp. 1429–1437, 2013.