

Smart E-Bike battery Health Monitoring System with Dual Battery Switching Mechanism

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Abstract

The increasing adoption of electric bikes (E-bikes) as an eco-friendly mode of transportation has highlighted the importance of battery health management and rider safety. Battery failures, sudden voltage drops, or overheating can lead to unexpected motor shutdowns, increasing the risk of accidents and inconvenience to the rider. This project presents a comprehensive health monitoring system for smart E-bikes that addresses these challenges by continuously tracking critical parameters such as the voltage levels of two separate batteries and battery temperature.

Keywords- IoT in electric vehicles, ThingSpeak cloud platform, ESP32 microcontroller, buzzer, DHT11 temperature sensor.

1. Introduction

Electric bikes (E-bikes) have gained widespread popularity as a sustainable and efficient alternative to conventional gasoline-powered vehicles. As the demand for cleaner transportation grows, maintaining the reliability and safety of E-bikes has become increasingly important. One of the critical factors affecting E-bike performance and user safety is the health and management of the battery system, which powers the motor. Batteries in E-bikes are prone to voltage drops, overheating, and sudden failures, which can result in unexpected motor shutdowns or damage to the electrical components. Such events not only disrupt the ride but can also lead to accidents, posing serious risks to the rider.

This project addresses these challenges by developing a Smart E-Bike Health Monitoring System that continuously monitors the voltage of two separate batteries and temperature of the battery pack. The system automatically switches power supply between the two batteries when the primary battery voltage falls below a certain threshold, ensuring uninterrupted operation of the motor. The

temperature sensor safeguards against overheating by disabling the motor if the temperature exceeds safe limits. Integrated with an ESP32 microcontroller, the system provides real-time data visualization on an LCD and uploads sensor readings to an online IoT platform, ThingSpeak, enabling remote monitoring. This combination of hardware and IoT technologies offers a comprehensive solution to improve the reliability, safety, and user experience of electric bikes, making them smarter and more efficient.

The Smart E-Bike Health Monitoring System aims to improve existing systems by offering real-time monitoring and control for electric bike users. It uses multiple sensors to track battery voltage levels and temperature. The system switches to a backup battery when the primary battery drops below 5V, ensuring continuous power. It also monitors temperature, preventing overheating by sending alerts and shutting down the motor if needed.

The system includes a buzzer for alerts on low voltage and high temperature, and a relay module to manage the motor's power supply. It features an LCD

display for real-time battery and temperature information and connects to WiFi for remote monitoring via the ThingSpeak IoT platform.

Overall, this integrated approach offers a smarter, safer, and more efficient E-bike health monitoring solution, ensuring uninterrupted operation and improved user confidence.

2. Related Work

K. Vishnu, A. Ojha, and R. K. Nema.,[1] discuss the need for an advanced battery management system to improve battery performance in electric vehicles. They propose using wireless technology to estimate and transfer battery parameters like voltage, current, and temperature to the BMS. Bluetooth is used for data communication.

Adhithya M. D., Arulmozhi M., Vishwa M., Kumar S.,[2] With more electric vehicles (EVs) being used, the need for charging stations is increasing. This paper proposes using radio-frequency identification (RFID) for user authentication and payment to prevent unethical unplugging of chargers. It also suggests monitoring battery health and performance in real-time through sensors and IoT technology, aiming to enhance charging efficiency, reduce costs, and support EV adoption..

Zhaona Lu., [3] Electric vehicles are gaining attention as a solution to the energy crisis and climate change, with a focus on power exchange technology. This paper examines the need for electric vehicles and analyzes their power exchange mode, emphasizing the importance of battery condition in this process. To monitor battery health in real-time during power exchange, a battery model is developed, and a Kalman filter algorithm estimates the battery state. A monitoring system using various components is constructed, achieving a simulation error of -0.4

Hatamoto M., Shigeyasu T., [4] Electric Vehicles (EVs) are seen as a solution to global warming, with Battery EVs (BEVs) being particularly appealing due to no carbon emissions. This study looks at Battery Swapping EVs, which allow for quick battery changes. However, developing this technology is costly, needing Battery Swapping Stations (BSS) and spare batteries. The study suggests using spare batteries as emergency power supplies and proposes a method for equalizing battery charge among BSSs through EV electricity transportation. It also

introduces a technique to minimize unnecessary battery transport while balancing electricity levels among BSSs.

Vishnu, K., Ojha, A., Nema, R. K., [5], In order to achieve better performance for a battery unit, an advanced battery management system must be required. Battery management system of an electric vehicles, one of the challenges facing is estimation of battery parameters and transferring the estimated data to BMS unit. This paper introduces wireless technology in battery management system. Using this wireless technology, the sensed data is collected and transferred to the battery management system main controller. Hardware implementation is done for a 48 V battery source and battery parameters such as voltage, current and temperature are sensed with the automotive-grade IC. Data communication executed by using Bluetooth technology.

Kosuru, V. S. R., and Kavasseri Venkitaraman, A., [6] Battery sensor data collection and transmission are vital for battery management systems (BMS). Inaccurate data from sensor faults, communication issues, or cyber attacks can harm BMS and affect applications like electric vehicles. Therefore, assessing the durability of battery sensor and communication and instruction. Dr. Ye Zhao is the corresponding author. The corresponding author's mailbox is zhaoye@ime.ac.cn

P. P. Joshi and S. M. Patil,[8] presents an IoT-based battery monitoring system for electric vehicles that continuously tracks parameters such as voltage, current, temperature, and state of charge. The system transmits real-time data to a cloud platform, enabling remote monitoring and alert generation during abnormal conditions. However, the system does not include automatic battery switching mechanisms.

M. A. Hannan, M. M. Hoque, A. Mohamed, and A. Ayob,[9] provides a comprehensive review of battery management systems (BMS) for electric vehicles, focusing on techniques such as state-of-charge (SOC) and state-of-health (SOH) estimation, thermal management, and fault diagnosis. Advanced methods including Kalman filtering and machine learning are discussed. However, the study is primarily theoretical and lacks real-time hardware implementation using IoT technologies.

S. Li, C. C. Mi, and M. Zhang,[10] proposes a smart battery management system with real-time

monitoring capabilities using sensors and embedded controllers. The system enhances safety by preventing overcharging and overheating through continuous monitoring and control. Although effective, it does not address dual-battery systems or automatic switching, which are key features of the proposed work.

3. Methodology

The smart e-bike health monitoring system software is created using the Arduino IDE for the ESP32 microcontroller. It continuously tracks sensor inputs, processes data, and controls outputs in real-time. Libraries are used to connect components like the DHT11 temperature sensor and an LCD display.

The system reads analog signals from the batteries, converting them into accurate voltage levels to assess battery conditions. It also monitors temperature with the DHT11 sensor, generating warnings if the temperature is too high. An automatic battery switching feature activates when the primary battery's voltage drops below a certain level.

A buzzer alerts users to critical issues, while the LCD shows real-time updates. The software includes fault detection to ensure safety. The system is tested and calibrated for accuracy and integrated into the e-bike for real-world evaluation. Software

Development: Program ESP32 to continuously read analog values from both voltage sensors and convert them to data is crucial. This research presents a system for detecting and classifying faulty data in lithium-ion batteries using deep learning. The process includes collecting sensor data,

voltage levels using the formula:

$$V = \left(\frac{\text{rawADC} \times 3.34095}{4095} \right) \times 5.0V =$$

preprocessing it, and selecting features. The proposed system improves safety and reliability in BMS, demonstrating better performance than traditional methods through simulations and experiments.

rawADC - The value read by ESP32's ADC (Integer between 0 and 4095 for a 12-bit ADC)

3.3 - Reference voltage (Vref)

5V - To get the real world voltage Read temperature data from the DHT11 sensor.

The smart e-bike health monitoring system uses battery switching logic to ensure continuous power and energy efficiency. It monitors the voltage of Battery 1 in real-time with a sensor connected to an ESP32 microcontroller. If Battery 1 drops below a safe voltage of 5V, the system activates switching logic. Relay 1, linking Battery 1 to the motor, is turned off to prevent damage, while Relay 2 connects Battery 2 to the motor for an uninterrupted power supply. This process is controlled to avoid issues like rapid switching, ensuring Battery 2 has enough voltage before powering the motor.

Additionally, the system controls the motor's operation based on voltage and temperature thresholds. The motor runs only when both conditions are safe. If either battery's voltage is low, or if the temperature is too high, the motor will turn off automatically to protect the components. A buzzer alerts the user to faults such as low voltage or overheating, providing distinct signal patterns for different issues, enhancing user awareness and preventing failures.

The LCD module is a key part of the smart e-bike health monitoring system, providing real-time information like battery voltage, temperature, and system status. It helps riders quickly check their e-bike's condition without extra tools, displaying alert messages for issues like low battery or high temperature. This makes the system user-friendly and enhances situational awareness. This process is controlled to avoid issues like rapid switching, ensuring Battery 2 has enough voltage before powering the motor.

The ESP32 microcontroller with Wi-Fi allows for remote monitoring, sending data to the ThingSpeak cloud platform. Users can access this data from anywhere, which includes battery and temperature readings logged for analysis. Graphs and charts on ThingSpeak help track trends and identify potential problems.

System integration ensures that all components work smoothly together under various simulated conditions, fine-tuning as necessary to reduce false alerts. After deployment on the e-bike, the system continuously monitors battery health and performance. Post-deployment feedback and data

analysis guide further improvements, ensuring the system remains effective and user-friendly.

A. BLOCK DIAGRAM

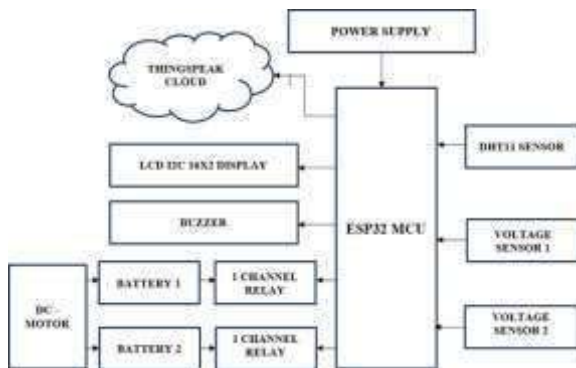


Fig. 1. BLOCK DIAGRAM

B. FLOW CHART

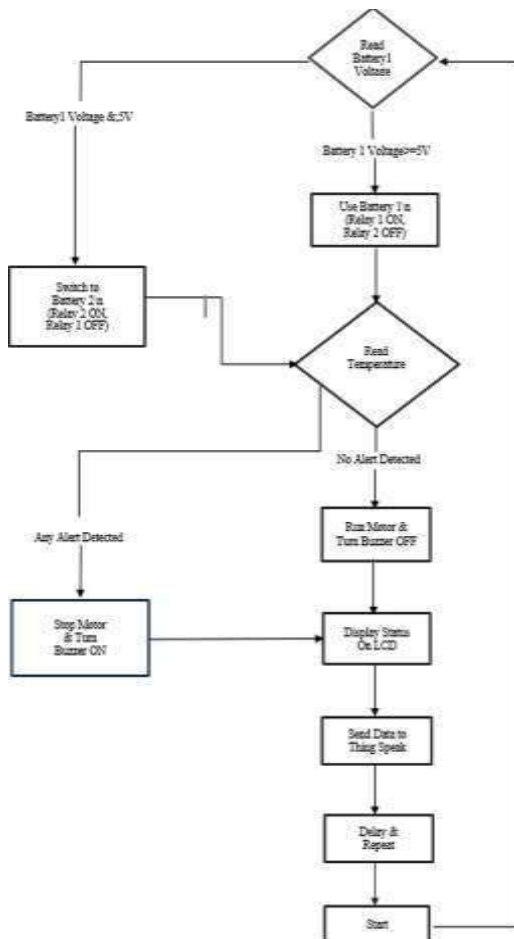


Fig. 2. FLOW CHART

C. COMPONENTS USED

ESP32 Microcontroller : Purpose: Acts as the brain of the system. Functions: Controls sensors, processes

logic, connects to Wi-Fi, and uploads data to ThingSpeak. **Features:** Dual-core processor, built-in Wi-Fi and Bluetooth, multiple ADC channels. **Voltage Sensors (x2)** Purpose: Measure voltage levels of two separate 12V lithium-ion batteries. **Function:** Used to monitor battery health and decide when to switch to the backup battery. **Relay Modules (x2)** Purpose: Used for switching motor power between batteries. **Function:** Re-lay 1: Controls connection to Battery 1. Relay 2: Controls connection to Battery 2 (backup). **Type:** 1-channel 5V relay modules (optocoupler based preferred). **DHT11 Temperature Sensor** Purpose: Measures ambient temperature. **Function:** If temperature exceeds the set threshold (e.g., 60°C), the motor is shut down to prevent overheating. **Buzzer** Purpose: Audible alert for system warnings or safety triggers. **Function:** Sounds when temperature is high, voltage is low. **Relay-Controlled Motor Load (Simulated DC Motor)** Purpose: Simulates electric bike's drive motor. **Function:** Relay turns ON/OFF based on system status. **Liquid Crystal Display (LCD) – I2C 16x2**

Purpose: Display real-time sensor data and alerts. **Function:** Shows voltage, temperature and motor status. **Wi-Fi Module (Built-in with ESP32)** Purpose: Send data to ThingSpeak IoT cloud. **Function:** Upload voltage, temperature, and status data for remote monitoring. **DHT11 Temperature Sensor** Purpose: Measures ambient temperature. **Function:** If temperature exceeds the set threshold (e.g., 60°C), the motor is shut down to prevent overheating.

D. SOFTWARE IMPLEMENTATION

Platform and Tools :The software is developed using the Arduino IDE, programmed in C/C++. The system runs on an ESP32 microcontroller that handles sensor readings, decision-making, and communication. **Libraries used:** WiFi.h – for connecting to WiFi networks. HTTPClient.h – to send data to cloud display via I2C. **Initialization** :The program begins by initializing all sensors, relays, buzzer, and the LCD display. The ESP32 attempts to connect to a predefined WiFi network for internet connectivity. After successful WiFi connection, the LCD displays a confirmation message. **Sensor Data Acquisition** :**Battery Voltage Monitoring:** The ESP32 reads the analog voltage from two voltage sensors connected to two different batteries (main and backup). **Temperature Monitoring:** Temperature data is retrieved from the DHT11 sensor. **Decision-**

Making Logic : The software continuously compares sensor readings against preset safety thresholds: Voltage threshold: If Battery 1 voltage $\leq$ 5V, switch to Battery 2. Temperature threshold: If temperature $\geq$ 60°C, stop the motor. Based on these conditions, the program controls the relays to switch power between batteries or turn off the motor. Output Control.

Relays: Relay 1 controls Battery 1 connection; Relay 2 controls Battery 2 connection. **Buzzer:** Activated when any unsafe condition is detected as an alert to the rider. **LCD Display:** Shows real-time data, including battery voltage, temperature and displays alert messages during fault conditions.

4. Results and Discussion (Size 10)

The Smart E-Bike Health Monitoring System was thoroughly tested to ensure reliable performance of all integrated components and accurate monitoring of key parameters such as battery voltages, temperature, and collision detection. The following key results were observed during the testing phase: **Battery Voltage Monitoring and Switching :** The system continuously monitored the voltage of two separate batteries using analog inputs. When the primary battery voltage dropped below the threshold of 5V, the system successfully switched to the secondary battery by toggling the respective relays. This switching ensured uninterrupted motor operation and demonstrated the effective implementation of backup power management. Both batteries were tested under varying load conditions, and the voltage readings displayed on the LCD matched those measured using a multimeter, confirming sensor accuracy. **Temperature Monitoring :** The DHT11 temperature relays to prevent overheating. The buzzer activated simultaneously as an alert, and the LCD displayed a warning message indicating high temperature. **Collision Detection :** The collision sensor, configured with an active low logic, was tested by simulating impacts. Upon collision detection, the system cut off the motor power and activated the buzzer alarm to alert the rider. This safety feature was validated multiple times to ensure rapid response to accidents. **LCD**

Display and User Interface : The 16x2 I2C LCD effectively displayed real-time data, including voltages of both batteries, temperature readings, and collision status. The messages were clear and

updated every 5 seconds **Cloud Data Monitoring :** Data was sent successfully to ThingSpeak, and the web dashboard showed real-time graphs of battery voltages, temperature, and collision alerts.



Fig. 3. Display of Battery-1



Fig. 4. Graph of



Fig. 5. Display of Battery-2



Fig. 6. Detection of



Fig. 7. Display of Battery-2



Fig. 8. Detection of

sensor accurately detected ambient temperature. When the temperature exceeded the set threshold of 60°C, the system immediately turned off the motor by disconnecting the battery



Fig. 9. Temperature displayed in LCD



Fig. 10. Graph of Temperature



Fig. 11. Working from battery 2

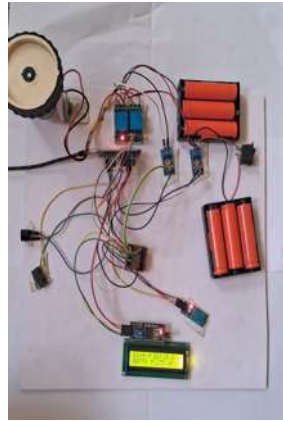


Fig. 12. Working from battery 1



Fig. 13. No collision detected (No accident detected)



Fig. 14. Accident detected [col-lision detected]



Fig. 15. Detection of temperature



Fig. 16. switching

battery voltage, temperature. the system proactively safeguards both the rider and the e bike from potential hazards and failures. The project achieved its key objectives, including: Real-time monitoring of

two battery sources and automatic switching during low voltage scenarios.

5. Conclusion

The Smart E-Bike Health Monitoring System successfully demonstrates how embedded systems and IoT technologies can be integrated to enhance the safety, reliability, and efficiency of electric vehicles. By monitoring critical parameters such as battery voltage, temperature. the system proactively safeguards both the rider and the e bike from potential hazards and failures. The project achieved its key objectives, including: Real-time monitoring of two battery sources and automatic switching during low voltage scenarios.

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