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SMART BATTERY MANAGEMENT SYSTEM WITH ELECTRONIS SPEED CONTROLLER AND IOT DASHBOARD FOR ANALYTICS

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ABSTRACT

The project aims to improve energy management systems for electric vehicles (EVs) and battery-powered devices by integrating a Battery Management System (BMS) with Electronic Speed Control (ESC). The BMS module monitors battery performance, while the ESC module allows for efficient motor control. The ESP32 microcontroller is the central processing unit, integrating with sensors, actuators, and cloud services. The ThingSpeak Cloud platform enhances diagnostic capabilities and predictive maintenance. The Kodular-based Android app provides a user-friendly interface for monitoring battery parameters and controlling motor operations. This integration of IoT-based monitoring and control mechanisms enhances energy management, making it ideal for modern electric mobility and industrial applications.

Keywords: Analysis, Electric Vehicle, Battery Management System. ESP32 Microcontroller Electronic Speed Controller.

I. INTRODUCTION

With the global shift towards renewable energy and sustainability, electric vehicles (EVs) and battery-powered devices are gaining widespread adoption. Efficient battery management and motor control play crucial roles in optimizing energy usage and ensuring system reliability. However, traditional battery management systems (BMS) and electronic speed control (ESC) solutions often lack real-time monitoring, predictive maintenance, and user-friendly interfaces. This project aims to bridge this gap by developing a comprehensive BMS integrated with ESC, powered by the ESP32 microcontroller, ThingSpeak Cloud, and a Kodular-based Android application.

Battery management is critical in extending the lifespan of lithium-ion batteries, which are widely used in EVs and portable electronic devices. The proposed BMS includes SOH monitoring, SOC estimation, overvoltage protection, and short-circuit prevention to ensure safe and efficient battery operation. Real-time data acquisition and cloud-based analysis enable proactive maintenance and system optimization.

Motor control is equally vital for EVs and battery-powered applications, as it dictates energy efficiency and operational performance. The ESC module in this project provides precise speed and direction control, allowing smooth acceleration and deceleration. The ESP32 microcontroller facilitates seamless integration between the BMS and ESC, ensuring real-time data processing and wireless communication with the cloud.

ThingSpeak Cloud is utilized for remote monitoring, enabling users to visualize critical battery and motor parameters, detect anomalies, and make informed decisions. The Kodular-based Android application provides an intuitive user interface, granting users the ability to monitor system parameters, control motor functions, and receive real-time notifications.

This project aims to enhance the efficiency and reliability of battery-powered applications by integrating intelligent monitoring, control, and user interaction features. The proposed system is applicable to EVs, robotics, industrial automation, and smart energy management, aligning with the future of sustainable technology.

II. METHODOLOGY

1. System Architecture

The system architecture of the Smart Battery Management System is show in Figure 1. The architecture is explained using a simplified diagram that describes the interaction of the technology involved in the proposed project. ESP32 microcontroller is used to interconnect with all sensors & Electronic Speed Control (ESC)

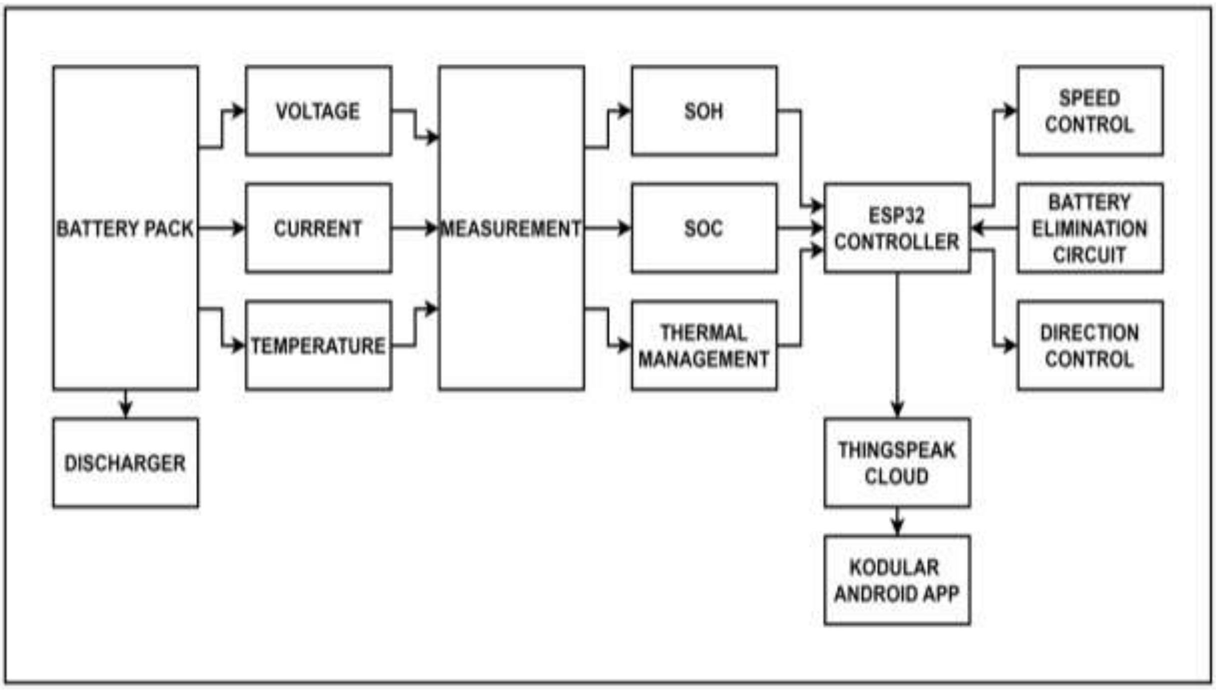

Figure 1: System Architecture

2. Battery Monitoring and Management

Step 1: Battery State of Charge (SOC) Estimation

- The BMS continuously measures the voltage, current, and temperature of the battery.
- Using these parameters, the system calculates the **State of Charge (SOC)** to determine how much energy is left in the battery.
- The SOC data is continuously updated to ensure accurate energy monitoring.

Step 2: Battery Health Monitoring

- The BMS monitors the **State of Health (SOH)** by analyzing battery capacity, internal resistance, and cycle count.
- If any parameter falls below a threshold (e.g., high internal resistance or low capacity), the system sends a warning to the user through the IoT dashboard.

Step 3: Data Collection & Monitoring

- **Battery data**:
  - Voltage, current, state of charge (SOC), state of health (SOH), and temperature are monitored by the BMS.
- **ESC data**:
  - Motor speed, torque, and efficiency data are captured by the ESC.
  - Control signals from the ESC to the motor (e.g., throttle input).
- **IoT Integration**:
  - Data from the BMS and ESC is transmitted via IoT to the cloud/server.
  - IoT module collects environmental data, such as ambient temperature, humidity, and system load

3. Data Handling

The ESP32 microcontroller serves as the core of the system, collecting real-time data from sensors and transmitting it to the ThingSpeak Cloud for storage and analysis.

The cloud platform provides visualization tools that allow users to assess battery health, charge levels, voltage, and motor speed remotely.

This data is then made accessible through the Kodular-based Android application, offering a user-friendly interface with interactive features such as setting speed limits, monitoring performance, and receiving alerts on critical battery conditions.

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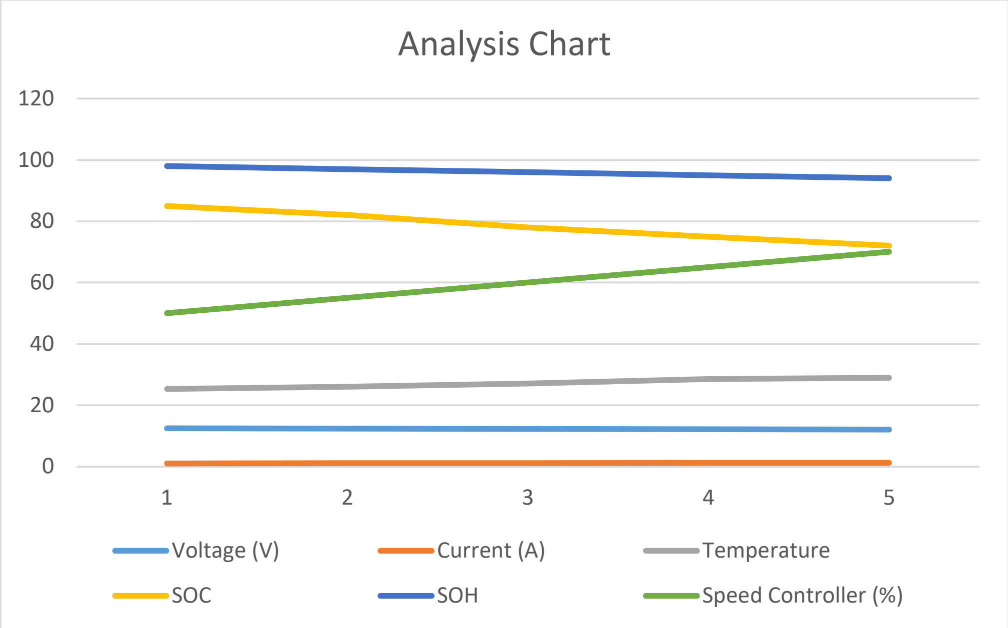
4. ANALYSIS



The visual graphs show how battery parameters evolve over time:

- **Voltage** and **SoC** decrease as usage progresses.
- **Temperature** steadily rises due to internal resistance and current load.
- **SoH** shows minor degradation, indicating aging or stress.
- **Speed Control** adjusts dynamically, reducing power draw under lower SoC/high temperature.

III. RESULTS AND DISCUSSION

The IoT-based Smart Battery Management System (BMS) developed in this project utilizes the ESP32 microcontroller, INA219 current/voltage sensor, DS18B20 temperature sensor, and additional software logic for estimating crucial battery parameters. These include State of Charge (SOC), State of Health (SOH), and the performance of a speed controller. The system continuously monitors and reports battery parameters, providing valuable real-time data for efficient management and maintenance.

Table 1: Observation Table

Observation No.	Voltage (V)	Current (A)	Temperature (°C)	SOC (%)	SOH (%)	Speed Controller (%)
1	12.45	1.05	25.3	85	98	50
2	12.38	1.10	26.0	82	97	55
3	12.30	1.15	27.1	78	96	60
4	12.20	1.20	28.5	75	95	65
5	12.10	1.25	29.0	72	94	70

1. State of Charge (SOC): The SOC gradually decreases over the course of observations, from 85% in Observation 1 to 72% in Observation 5. This decrease in SOC is expected as the battery is used to supply current for the connected load. The rate of SOC drop depends on the current consumption, where higher current draw leads to faster depletion. This is an important metric for users to determine when the battery needs recharging.

2. State of Health (SOH): The SOH values show a slight but steady decrease from 98% in Observation 1 to 94% in Observation 5. A decrease in SOH indicates that the battery is gradually losing its capacity to hold charge and perform efficiently. This could be attributed to several factors such as age, frequent discharging cycles, or high temperatures. Monitoring SOH over time provides users with valuable insights into the battery's lifespan and whether it needs to be replaced.

3. Voltage and Current Measurements: The voltage readings slowly drop over the course of observations, with the voltage going from 12.45V to 12.10V. This slight drop is expected as the battery discharges. Current measurements also show an increasing trend, starting from 1.05A in Observation 1 and rising to 1.25A in Observation 5. This increase could be attributed to a higher load being applied to the system, leading to higher current draw and therefore, faster depletion of SOC.

4. Temperature Monitoring: The battery's temperature rises from 25.3°C to 29.0°C, which is a typical range for most lithium-ion batteries under load. However, if the temperature exceeds safe operating limits (usually around 40-45°C), it could indicate a problem with the battery's health, excessive load, or inadequate cooling. The DS18B20 temperature sensor plays a critical role in ensuring the battery operates within safe thermal limits, preventing overheating that could cause permanent damage or reduce the SOH.

5. Speed Controller Readings: The speed controller readings gradually increase, indicating that the system is adjusting to higher demand. The increasing load or operational demand could be seen as a higher performance demand on the battery, which correlates with the increase in current draw. The system must ensure that the speed controller operates within the power limits of the battery to avoid deep discharges or excessive wear on the battery.

IV. CONCLUSION

The project combines a Battery Management System (BMS) with Electronic Speed Control (ESC) using an ESP32 microcontroller, offering real-time monitoring and control of battery parameters. The system uses ThingSpeak Cloud for data visualization and a Kodular-based Android application for remote monitoring. This technology optimizes energy usage, enhances safety, and extends battery life. Real-time monitoring improves predictive maintenance, reduces unexpected failures, and increases efficiency. The seamless communication between hardware and cloud-based system provides a modern, accessible, and scalable approach to battery and motor management.

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