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IoT Based Battery Management System

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***Abstract*— This paper presents an IoT-enabled Battery Management System (BMS) designed for electric vehicles, focusing on real-time monitoring and control of lithium-ion battery parameters. Utilizing a PIC microcontroller, the system ensures battery safety and efficiency through automated charging, temperature regulation, and cloud-based data visualization. The solution enhances battery lifespan and lays the foundation for future advancements in smart EV energy management.**

***Keywords*— Internet of Things (IoT), State of Charge (SoC), PIC Microcontroller, Temperature Monitoring, Real- Time Data, Battery Safety.**

I. INTRODUCTION

A. INTERNET OF THINGS

The Internet of Things, refers to the network of physical devices, vehicles, appliances, and other objects embedded with sensors, software, and connectivity, enabling them to connect and exchange data. These connected devices can communicate with each other and with humans, creating a vast network of interconnected systems. IoT has numerous applications across various domains, including smart homes, healthcare, transportation, agriculture, and industrial automation. It enables automation, data collection, analysis, and remote control, leading to improved efficiency, convenience, and insights. In simpler terms, IoT connects everyday objects to the internet, making them "smart" and capable of interacting with us and each other. It's like having a world where everything is interconnected and can work together to make our lives easier and more efficient.

B. SCOPE AND OBJECTIVES

The scope of this project includes the development of an IoT-enabled Battery Management System (BMS) specifically designed for electric vehicles. The key objectives are to ensure safe and efficient operation of lithium-ion batteries by enabling real-time monitoring of voltage, current, and temperature, along with automated control of charging and discharging processes. Temperature monitoring plays a crucial role in maintaining thermal safety and preventing battery degradation. The system also estimates the State of Charge (SoC) and State of Health (SoH) to optimize performance and extend battery life. Integration with cloud platforms allows for remote data visualization and opens pathways for future enhancements such as scalability, intelligent analytics, and mobile connectivity

II. SYSTEM DESCRIPTION

The proposed IoT-enabled Battery Management System (BMS) is centered around a PIC microcontroller and designed to ensure the safe and efficient operation of an
11.2V lithium-ion battery pack used in electric vehicles. The system receives power through a step-down transformer connected to a charging circuit, which is regulated by relays for automated control of the charging process. The microcontroller continuously monitors key battery parameters — voltage, current, and temperature — using dedicated sensors. These sensor outputs are digitized through an ADC converter and processed to assess the battery's operational status in real time.

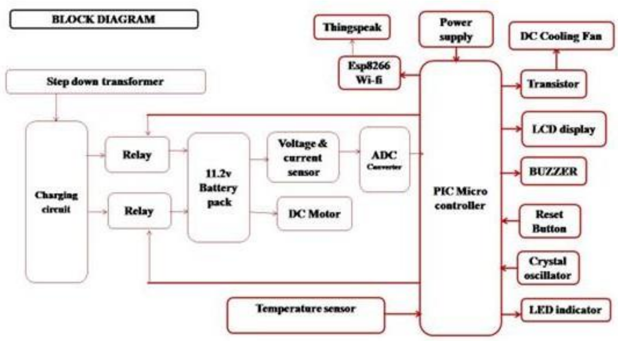

Fig. 1. Block Diagram of proposed system

The system features multiple peripheral components to enhance safety and usability. A DC cooling fan, controlled by a transistor, helps maintain thermal stability based on temperature readings. An LCD display provides live battery data locally, while alerts are issued through a buzzer and LED indicators. The inclusion of a reset button and a crystal oscillator ensures stable system operation. For remote monitoring and data logging, sensor data is transmitted to the ThingSpeak cloud platform via an ESP8266 Wi-Fi module. This setup allows users to track battery health remotely, supporting predictive maintenance and future integration with smart energy management systems.

III. CIRCUIT LAYOUT

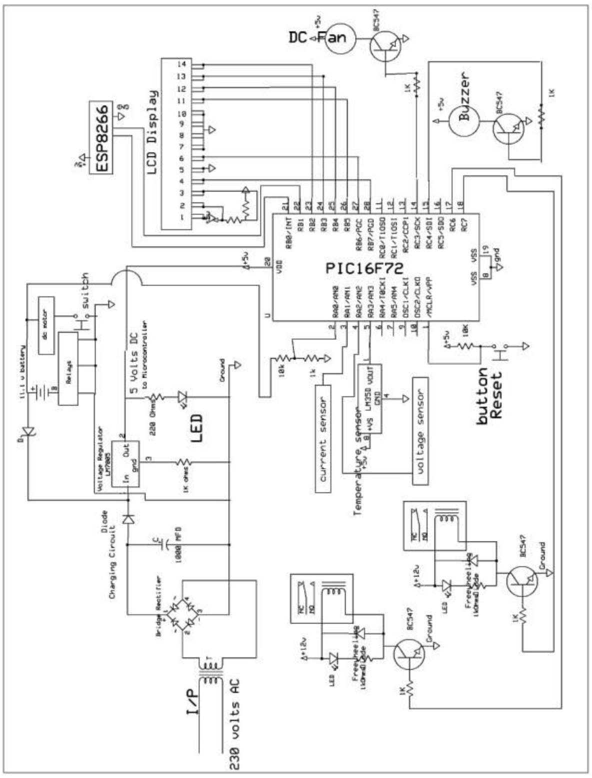

Fig.2. Circuit Layout

IV. SOFTWARE IMPLEMENTATION

The software implementation for the PIC microcontroller is carried out using PIC C compiler, enabling efficient development of embedded C code optimized for real-time operations. The program is structured into modular functions to handle sensor data acquisition, signal processing, device control, and cloud communication. Analog sensor inputs for voltage, current, and temperature are interfaced with the microcontroller's ADC channels, and sampled periodically to monitor battery conditions accurately.

Upon processing the sensor values, the software executes control logic to manage the charging process through relay activation and triggers the DC cooling fan via a transistor when temperature thresholds are breached. The LCD module is updated in real-time to display vital battery parameters such as voltage, current, temperature, and system status. UART communication is used to interface the PIC microcontroller with the ESP8266 Wi-Fi module, enabling the transmission of processed sensor data to the ThingSpeak cloud platform at regular intervals. Error handling routines and threshold-based alerts (via buzzer and LEDs) are integrated into the program to enhance system reliability and user safety. This software implementation ensures coordinated control, remote accessibility, and adaptability for advanced battery management in electric vehicle applications.

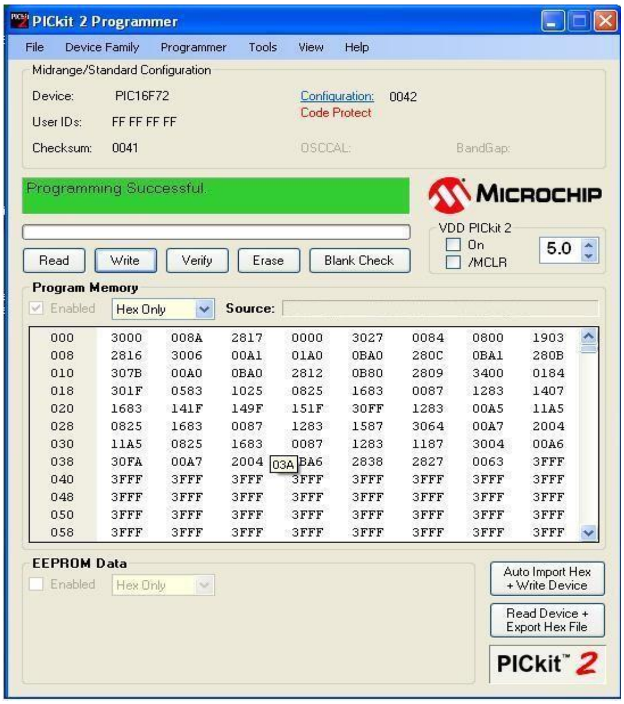

Fig.3.Program dumped into the microcontroller

V. HARDWARE IMPLEMENTATION

The proposed IoT-based Battery Management System (BMS) is engineered to provide real-time monitoring, safety assurance, and intelligent control of lithium-ion batteries used in Electric Vehicles (EVs). Upon powering up via a regulated supply, the PIC microcontroller initializes all system components, including the ESP8266 Wi-Fi module, LCD display, and integrated sensors for voltage, temperature, and current. The system continuously reads voltage levels from each battery pack and triggers the appropriate relay to initiate charging when a battery's voltage drops below a set threshold. Relays are employed to ensure isolated and safe charging of individual battery packs. Simultaneously, temperature is monitored using an LM35 sensor. If excessive heat is detected, the system responds by activating a cooling fan and alerting the user through a buzzer, thus maintaining thermal safety.

To provide users with local and remote feedback, the system utilizes a 16x2 LCD to display real-time values such as voltage, temperature, and charging status. LED indicators supplement this by offering visual cues for charging activity and fault conditions. The ESP8266 module enables the transmission of sensor data to the ThingSpeak cloud platform, facilitating remote monitoring, graphical data visualization, and long-term performance analysis. Additionally, the system estimates the State of Charge (SoC) based on voltage readings using predefined algorithms, offering insights into battery availability and efficiency. A DC motor is included to simulate load conditions, allowing the BMS to be tested under real-time discharge scenarios. This comprehensive integration of sensing, control, and IoT functionality ensures the system is a robust and scalable solution for modern electric vehicle battery management.

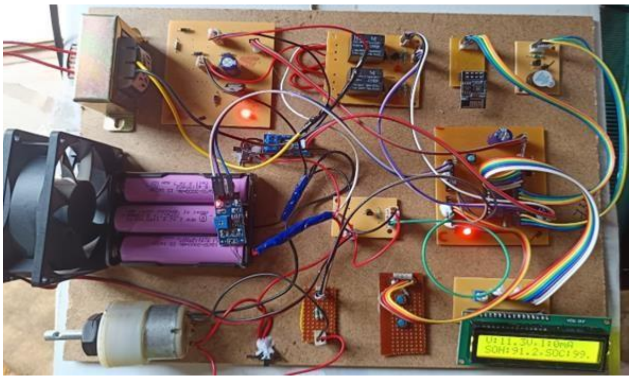

FIG.4. PROPOSED MODEL OF IOT BASED BMS

VI. RESULTS AND DISCUSSIONS

The developed IoT-based Battery Management System (BMS) was rigorously tested under simulated conditions, demonstrating reliable performance in real-time monitoring, automated safety control, and remote data integration. The system accurately measured voltage, current, and temperature using appropriate sensors, and the PIC microcontroller efficiently managed charging through relay activation when voltage thresholds were met. Temperature control was responsive, with the cooling fan and buzzer activating promptly during overheating scenarios. Real-time data was clearly displayed on the 16x2 LCD, with LEDs and buzzers providing immediate alerts for fault conditions. Cloud connectivity via the ESP8266 Wi-Fi module and ThingSpeak platform allowed for consistent data transmission and visualization, enabling users to track battery parameters remotely. The State of Charge (SoC) estimation provided useful insights into battery capacity, while tests with a DC motor load validated the system's discharge management capabilities. Overall, the BMS proved to be a robust, scalable, and user-friendly solution for improving battery efficiency and safety in electric vehicle applications.

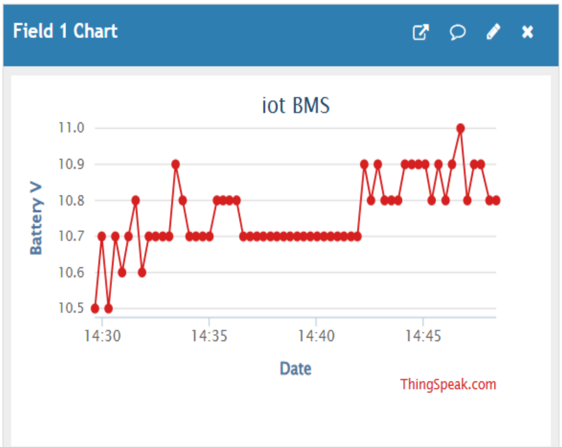

Fig.5.Battery Voltage

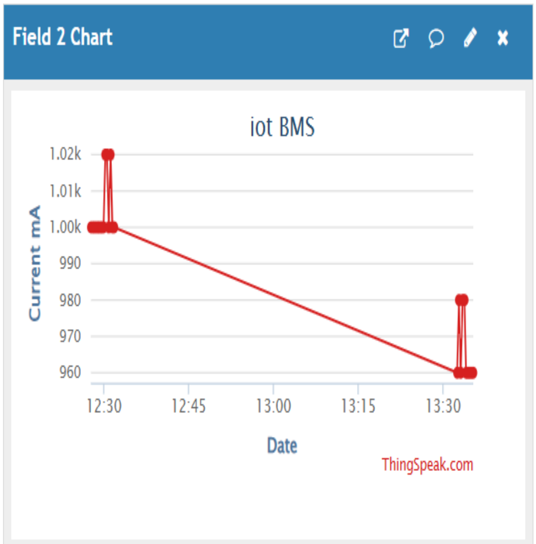

Fig.6. Current

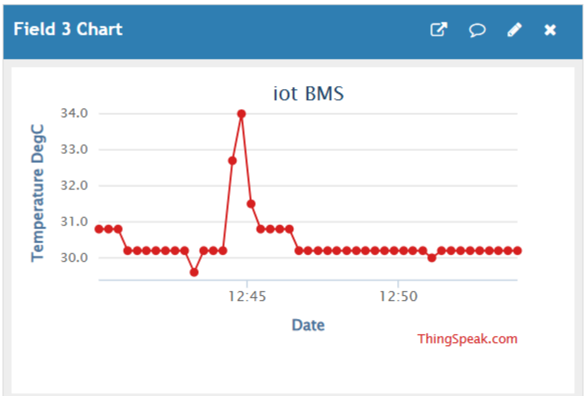

Fig.7. Temperature

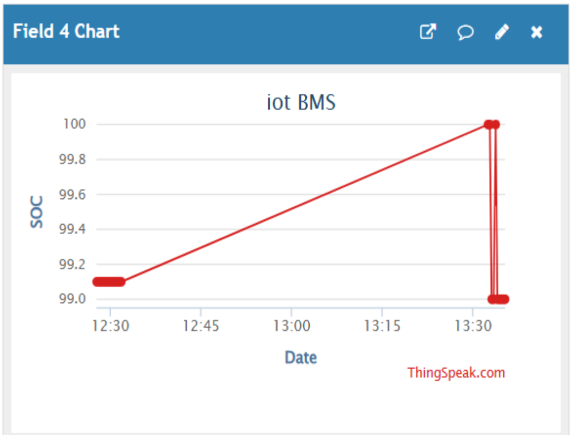

Fig.7. SoC

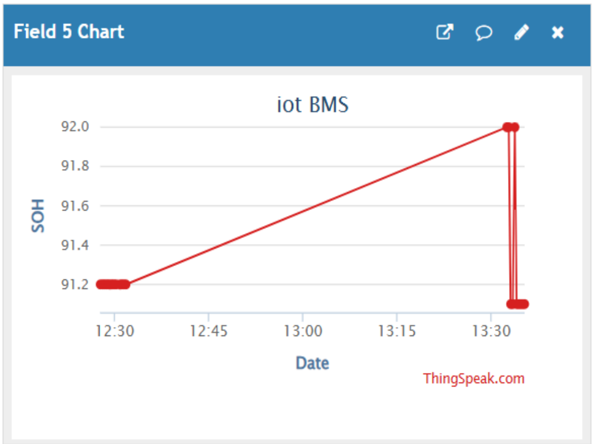

Fig.8. SoH

Fig.9. Voltage, Current, SOC, SOH values on LCD

VII. CONCLUSION

The developed IoT-based Battery Management System (BMS) offers an effective and intelligent solution for ensuring the safe operation, real-time monitoring, and efficient control of lithium-ion batteries in electric vehicles. With accurate sensing of voltage, current, and temperature, automated charging and thermal safety mechanisms, and seamless cloud integration via ThingSpeak, the system enhances battery reliability and user accessibility. The inclusion of State of Charge (SoC) estimation and successful load testing with a DC motor further validate its practical utility. Overall, the system proves to be a scalable and robust platform for next-generation EV battery management.

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