SMART BATTERY MANAGEMENT SYSTEM FOR ELECTRIC VEHICLES USING IOT

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ABSTRACT

The rapid adoption of electric vehicles (EVs) has increased the demand for efficient and reliable battery management systems (BMS) to ensure performance, safety, and longevity. This project presents a Smart IoT-Based Battery Management System designed for small to mid-sized EVs, integrating real-time monitoring, safety mechanisms, and remote accessibility. The system employs sensors to track voltage, current, temperature, and fire hazards, with data processed by an Arduino Uno and communicated via NodeMCU to cloud platforms. A 16x2 LCD provides local display, while a buzzer and relay enable immediate safety responses such as alerts and load disconnection. The inclusion of an ultrasonic sensor adds collision and proximity detection capabilities. By combining IoT connectivity with traditional BMS functions, the proposed system offers predictive maintenance, improved operational safety, and user-friendly monitoring through smartphones or dashboards. Experimental results validate the system's effectiveness in detecting anomalies, preventing hazardous conditions, and supporting remote diagnostics, making it a cost-effective solution for educational, prototype, and practical EV applications.

Keywords: Arduino Uno, Current Sensor, Voltage Sensor, Ultrasonic Sensor, Relay, NodeMCU, Fire Sensor, LCD & Buzzer

I.INTRODUCTION

The rapid growth of the electric vehicle (EV) industry is reshaping the global transportation landscape by providing a cleaner, more sustainable alternative to traditional internal combustion engine vehicles. One of the most critical aspects of EV technology is the Battery Management System (BMS), which ensures the optimal performance, safety, and longevity of the battery pack. As battery technology advances, integrating the Internet of Things (IoT) into BMS design has opened up new possibilities for real-time monitoring, remote control, and predictive maintenance.

This project, titled "Smart Battery Management System for Electric Vehicles using IoT", focuses on designing and implementing an intelligent system that monitors key parameters of an EV battery, such as voltage, current, temperature, and potential fire hazards. The system aims to prevent failures and enhance safety by incorporating sensors, microcontrollers, and IoT connectivity. By leveraging this smart approach, the project contributes to building a more robust and user-friendly EV infrastructure.

II. LITERATURE REVIEW

T. Sirisha et al. in [1] discuss the importance of battery monitoring for electric vehicles and introduces a Battery Management System (BMS) that can help ensure the safety and optimal performance of the battery system. The BMS is designed to monitor the battery at all times and measure the temperature at each battery cell during charging and discharging. The State of Charge (SOC) estimation is implemented using Coulomb counting method and the State of Health (SOH) of the battery is determined using CCCV. The paper also discusses the use of IoT to automatically store the battery, temperature, and voltage data on the website of Thing Speak.

The authors emphasize the importance of thorough investigation of batteries to quickly address any problems that may arise. Overall, the paper provides a comprehensive overview of the development of a BMS for electric vehicles and highlights the importance of battery monitoring for the safety and performance of electric vehicles. The authors emphasize the importance of thorough investigation of batteries to quickly address any problems that may arise. Overall, the paper provides a comprehensive overview of the development of a BMS for electric vehicles and highlights the importance of battery monitoring for the safety and performance of electric vehicles.

Raj Patel et al. in [2] provides an overview of Battery Management System (BMS) technologies used in Electric Vehicles (EV) and Energy Storage Systems. The paper discusses the importance of BMS in controlling and monitoring, charging and discharging of batteries and maintaining reliability and safety. The key components of BMS, including feedback and control systems, cell voltage feedback, temperature feedback, and power misfits are explained. The paper also covers State of Charge (SOC), State of Health (SOH), Thermal management, and Battery SOC modelling. Overall, the paper provides a comprehensive understanding of BMS technologies and their importance in EV and Energy Storage Systems.

A battery management system consists of: (1) a battery-level monitoring system (2) an optimal charging algorithm and (3) a cell/thermal balancing circuitry. The voltage, current and temperature measurements are used to estimate all crucial states and parameters of the battery system, such as the battery impedance and capacity, state of health, state of charge, and the remaining useful life.

Muhammad Nizam et al. in [3] provide an overview of the design of a Battery Management System (BMS) for Lithium-Ion batteries. It discusses the importance of BMS in prolonging the lifespan of Lithium-Ion batteries and ensuring their safe operation. The paper reviews the basics, progress, and challenges of Lithium-Ion batteries, and their use in electric vehicles. It also provides an overview of the application of BMS in smart grids and electric vehicles.

The paper discusses the classification and overview of commercial Lithium-Ion battery charging strategies, including constant current charging, constant voltage charging, and pulse charging. It also explores the use of Battery-based neural and particle networks for predicting the useful life of Lithium-Ion batteries. Overall, this paper provides valuable insights into the design of battery management systems for Lithium-Ion batteries and the challenges and opportunities associated with their use in electric vehicle system and smart grids.

Harish. N et al. in [4] is titled "IOT Based Battery Management System" and was published in the International Journal of Applied Engineering Research in 2018. The paper discusses the use of Internet of Things (IoT) technology to monitor and manage the performance of vehicular batteries, with a focus on lead-acid batteries. The authors propose a system that uses sensors to monitor important battery parameters such as voltage and temperature, and sends this data to the cloud for analysis. The system also includes a control unit that can take actions such as disconnecting the battery from the vehicle in case of overcharging or overheating. The authors conclude that their system can help improve the performance and lifespan of vehicular batteries, and can be extended to other types of batteries as well.

S. Prabakaran et al. in [5] discuss the importance of monitoring the battery's state in electric vehicles and how battery monitoring system based on IoT can help ensure efficient and reliable use of EVs. The proposed system consists of various modules, including a power supply, ATMEGA328P microcontroller, battery, voltage sensor, temperature sensor, smoke sensor, NodeMCU, relay, DC motor, LCD, and buzzer. The system tracks the health of the battery by monitoring various parameters such as voltage, temperature, and smoke levels. The data is transmitted to a cloud-based server using the NodeMCU module, where it is analyzed and used to generate alerts and notifications for the user.

The paper also discusses the benefits of using an IoT-based battery monitoring system for electric vehicles, including improved battery life, reduced maintenance costs, and increased safety. The system can help prevent battery failures and extend the life of the battery by providing real-time data on its health and performance. The cloud-based server can also be used to generate reports and analytics, which can be used for the improvement of overall efficiency of the electric vehicle and optimizes the performance of the battery. The paper includes references to various studies and research papers on battery management systems and IoT technology, including a study by Hu et al. on the use of IoT based systems for management of battery in electric vehicles.

III. PROBLEM STATEMENT

Traditional battery management systems are limited by offline diagnostics and reactive safety mechanisms. They often cannot communicate data externally or predict failures before they occur. Moreover, in cases of battery overheating or overcurrent, the system might only initiate protection after damage has already begun.
The lack of real-time monitoring, remote diagnostics, and proactive alert systems significantly impacts EV battery reliability, user safety, and maintenance efficiency. Additionally, the absence of integrated fire detection and temperature control systems makes current solutions inadequate for future EV requirements.

IV.PROPOSED METHOD

Batteries in electric vehicles (EVs) degrade over time due to chemical reactions, reducing their energy storage capacity. To mitigate degradation, controlling charging and discharging profiles, especially under varying conditions, is essential. Battery life is also affected by factors like temperature fluctuations and frequent high-current charge/discharge cycles. Despite occasional safety concerns, well-designed EV systems with safety features and automatic cutoffs are generally secure. Flexible Battery Management Systems (BMS) that can cover various battery types and offer comprehensive protection have become a focus of recent EV development. State of charge is a critical parameter for safe battery charging and discharging. It represents the battery's current capacity relative to its rated capacity. SOC helps manage voltage, current, temperature, and other battery-related data. Accurate SOC calculation prevents overcharging and over discharging, which can damage batteries. Additionally, the safety and sustainability of energy storage solutions are paramount concerns, especially in applications like electric vehicles, renewable energy grids, and portable electronic gadgets.

V.BLOCK DIAGRAM

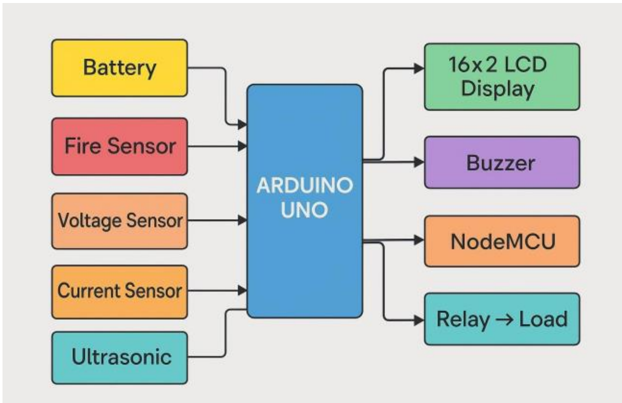


Fig Block Diagram

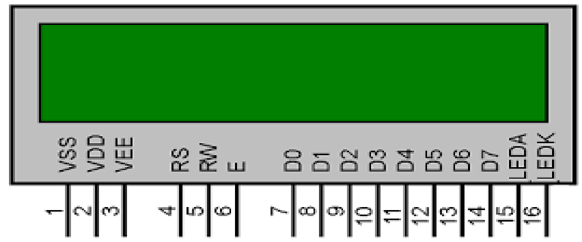
ARDUINO UNO

The Arduino Uno R3 is a microcontroller board featuring the ATmega328 chip. It offers 14 digital input/output pins (6 PWM capable), 6 analog inputs, USB connectivity, a power jack, and various headers for expansion. Unlike previous versions, it utilizes the Atmega16U2 chip for USB-to-serial conversion. Revision 3 introduces enhancements like additional pins for compatibility with future shields, a stronger reset circuit, and the replacement of the 8U2 chip with the 16U2. The name "Uno" signifies its status as the reference model for the Arduino platform, particularly with the release of Arduino 1. 0.

RELAY

Relays are used in a wide variety of applications. The advantage of relays is that it takes a relatively small amount of power to operate. Relays are simple switches which are operated both electrically and mechanically. Relays consist of an electromagnet. It also contains a set of contacts. The switching mechanism is based on electromagnet. Most of the devices have the application of relays.

LCD



It is called Liquid Crystal Display. We are going to use 16x2 characters LCD. This will be connected to microcontroller. The job of LCD will be to display all the system generated messages coming from the controller. LCD will provide interactive user interface. This unit requires +5VDC for its proper operation. This module is used for display the present status of the system.

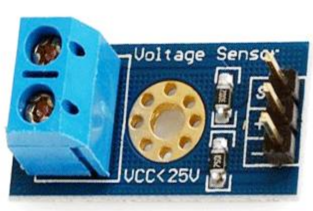
BATTERY

The fundamental principles of how batteries work. When two dissimilar metals are placed in an electrolyte solution, one metal gains electrons (becoming the cathode) while the other loses electrons (becoming the anode), based on their respective electron affinities. This creates a potential difference, or voltage, between the metals. The process involves oxidation and reduction reactions at the electrodes, leading to the production of negative and positive ions in the electrolyte solution. This potential difference can then be utilized as a source of voltage in electronic or electrical circuits. In summary, batteries function by harnessing the chemical reactions between metals and electrolytes to generate electrical energy.

FLAME SENSOR

The flame sensor detects flame or high-temperature conditions that may signal the presence of fire. It helps provide early warning to prevent damage, especially in battery systems where overheating can cause explosions. The commonly used sensor is a flame sensor module with an infrared receiver that detects specific wavelengths emitted by fire.

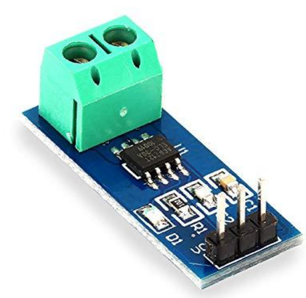
VOLTAGE SENSOR



Sensors offer several advantages over conventional measuring techniques, including small size and weight, enhanced personnel safety, high accuracy, non-saturation, wide dynamic range, and eco-friendliness. They can integrate voltage and current measurements into a single compact device.

Focusing on voltage sensors, they excel in determining, monitoring, and measuring voltage supply, whether AC or DC. Voltage sensors can produce various output signals such as analog voltage, switches, audible signals, current levels, or frequency modulation. They operate based on voltage dividers and come in two main types: capacitive and resistive. Capacitive sensors rely on changes in capacitance, while resistive sensors utilize changes in resistance to measure voltage levels. These sensors play a crucial role in various applications where accurate voltage monitoring is essential.

CURRENT SENSOR



A current sensor detects electrical current in a wire and generates a proportional signal. In a Hall effect-based sensor, magnetic flux from the primary current induces a Hall voltage in a gapped magnetic core containing a Hall effect device. This voltage is further amplified to provide an output proportional to the primary current, offering galvanic isolation.

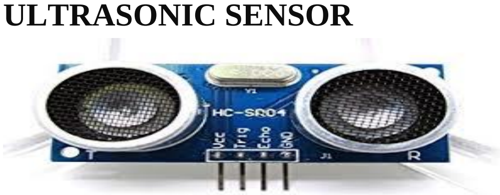
In a closed-loop sensor, a secondary coil and feedback circuitry are added. This 'zero-flux' sensor feeds back an opposing current into the secondary coil to nullify the flux produced by the primary current, providing an exact representation of the primary current with galvanic isolation.

The output of a closed-loop sensor can be scaled using a burden resistor to produce a voltage output proportional to the primary current. Overall, current sensors play a crucial role in measuring current accurately and safely for various applications.

ESP8266 WI-FI MODULE:

This is the heart of the project. Since the project is based on WIFI control of appliances, the module forms the important component of the project. The ESP8266 Arduino compatible module is a low-cost Wi-Fi chip with full TCP/IP capability, and the amazing thing is that this little board has a MCU (Micro Controller Unit) integrated which gives the possibility to control I/O digital pins via simple and almost pseudo-code like programming language. This device is produced by Shanghai-based Chinese manufacturer, Es press if Systems.

ULTRASONIC SENSOR



Ultrasonic sensors (also known as transceivers when they both send and receive) work on a principle similar to radar or sonar which evaluate attributes of a target by interpreting the echoes from radio or sound waves respectively. Ultrasonic sensors generate high frequency sound waves and evaluate the echo which is received back by the sensor. Sensors calculate the time interval between sending the signal and receiving the echo to determine the distance to an object.

HC-SR04 distance sensor is commonly used with both microcontroller and microprocessor platforms like Arduino, ARM, PIC, Raspberry Pie etc. The following guide is universally since it has to be followed irrespective of the type of computational device used.

BUZZER:

A buzzer or beeper is an audio signaling device used for various purposes such as alarms, timers, and user input confirmation. There are two main types: electromechanical and electronic.

Electromechanical buzzers are based on an electromechanical system similar to an electric bell but without the metal gong. They typically involve a relay connected to interrupt its own actuating current, producing a buzzing sound. These buzzers were often mounted on walls or ceilings to amplify the sound.

Electronic buzzers utilize a piezoelectric element driven by an oscillating electronic circuit or audio signal source. They produce sounds like clicks, rings, or beeps to indicate actions such as button presses. Electronic buzzers are widely used in modern applications due to their versatility and reliability.

VI.RESULT

The Smart IoT-Based Battery Management System for Electric Vehicles was successfully designed, built, and tested as a working prototype. The system effectively monitored real-time parameters such as voltage (observed at 2.8V during testing), current, fire presence, and distance using appropriate sensors integrated with an Arduino Uno and NodeMCU. The LCD displayed live data, while the NodeMCU enabled cloud-based remote monitoring.

Fig Voltage measurement

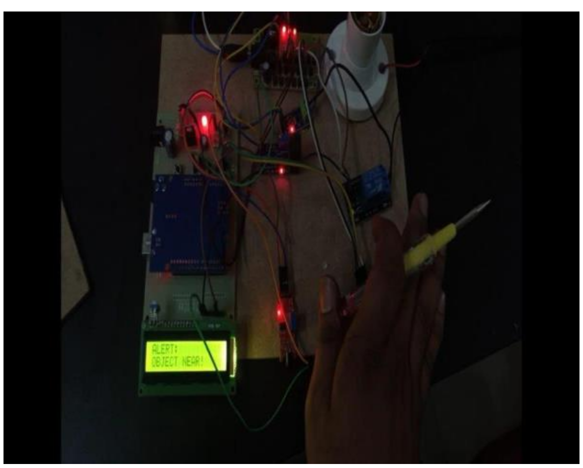
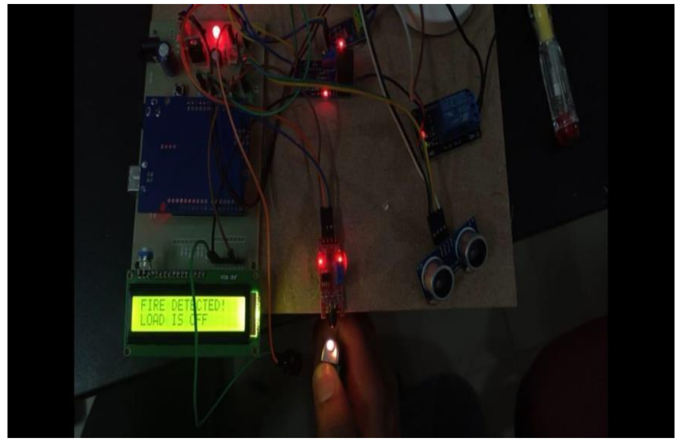


Fig Ultrasonic detection

Fig Fire detection



VII.APPLICATIONS

Electric vehicles: Scooters, bikes, and passenger cars.

Solar power storage systems.

Smart homes using battery backup.

Industrial battery banks for UPS systems or automation.

It is especially useful in high-temperature environments or remote regions where frequent physical monitoring is difficult.

VIII.CONCLUSON AND FUTURE WORK

It is very important for BMS to well-maintained the battery reliability and safety, the state monitoring and evaluation, cell balancing and charge control are well functional. Thus, this present paper is review on BMS, focusing study for optimization of BMS that will lead to reliability of BMS and optimize power performance. Monitor the battery anywhere in the world using IoT. It's taking the data from IoT embedded sensor and transmit the cloud. Provide better performance to user enhance the battery life.

This IoT based battery management system help us to monitor the battery conditions and also help us to monitor the battery health. Further we added the more sensor for humidity management and finding the efficient option for battery temperature and battery colling. we think about battery cooling and for that we will used solid colling material. This material automatically melts when battery getting hot and after battery cold. It will again get again it's first stage mean it again got it first stage which was solid. We think about fully system is make as AI. We want to made an AI Based Battery management system. In this AI fully system is controlled by AI. Few things only handle by human hand.

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