BATTERY PROTECTION AND HEALTH MONITORING SYSTEM USING IOT CLOUD

Dr. M. Revathi , Assistant Professor, Department of Electrical Engineering, Andhra University College of Engineering For Women, Visakhapatnam, Andhra Pradesh, India.
J. Sharmila , Student, Department of Electrical Engineering, Andhra University College of Engineering For Women, Visakhapatnam
N. Sai Sushma, Student, Department of Electrical Engineering, Andhra University College of Engineering For Women, Visakhapatnam
K. Praseeda, Student, Department of Electrical Engineering, Andhra University College of Engineering For Women, Visakhapatnam
G. Jyothi Swaroopa , Student, Department of Electrical Engineering, Andhra University College of Engineering For Women, Visakhapatnam
Ayesha Siddiqua, Student, Department of Electrical Engineering, Andhra University College of Engineering For Women, Visakhapatnam

Abstract
The increasing emphasis on renewable sources in today's world highlights the significance of electric vehicles as the optimal choice for environmentally friendly mode of transportation. Thus, the battery becomes essential component. Rechargeable batteries are vital components in various applications including electric vehicles. Ensuring their efficient operation, longevity, and safety is crucial. The creation of an effective Battery Monitoring System is necessary to accomplish this. Such a system would prevent overcharging or significant discharging of batteries. Efforts to track the performance of electric vehicles has increased due to their increasing global popularity. This paper presents Battery protection and health monitoring system that provides actual time battery status warnings to the individual who uses it. The battery health monitoring system through cloud is designed to monitor and safeguard rechargeable battery systems while providing real-time data analysis and visualization through the ThingSpeak IoT platform. In order to monitor vital battery metrics including current, temperature, and voltage and the battery's state of charge (SOC) and health (SOH), this system combines Internet of Things technology with battery safety measures.
Keywords: Li-ion battery, ESP 32

1.Introduction

One of the most crucial elements in Electric vehicle, is the battery management system, particularly when employing lithium-ion batteries. The travel range of an electric vehicle (EV) is often restricted by the size of its battery and the design of its body. Currently, one significant factor limiting the use of electric vehicles is the safety of current battery technology. An overcharged battery can cause a major accident in addition to drastically reducing its lifespan. The rapid proliferation of rechargeable battery technologies across diverse industries underscores the critical importance of effective battery management systems. As these batteries serve as energy storage solutions in an array of applications, ensuring their optimal performance, longevity, and safety is paramount. The introduction of IoT (Internet of Things) technology has revolutionized the way we monitor and manage complex systems, offering real-time insights, remote accessibility, and predictive analytics capabilities. Leveraging the power of IoT, the Battery Protection and Health Monitoring System using ThingSpeak server emerges as a sophisticated solution to address the challenges associated with battery management. This system monitors vital indicators including voltage, current, temperature, state of health and the state of charge (SoC) of rechargeable battery cells by integrating sensors, microcontrollers, and wireless communication protocols. The ThingSpeak IoT platform serves as the backbone of the monitoring system, providing a centralized cloud-based infrastructure for data

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 5, No.6, May : 2024
storage, analysis, and visualization. Through the ThingSpeak platform, users gain access to a suite of tools for data logging, alerting, and visualization, empowering them to make informed decisions regarding battery health and performance.
The project's motivation lies in addressing climate change by reducing greenhouse gas emissions through Electric Vehicles (EVs), which utilize electricity as a cleaner energy source. With the increasing trend in EV adoption, ensuring proper battery maintenance is crucial for improving vehicle lifespan. By implementing effective monitoring and precautions for battery usage, the project aims to enhance EV durability while fostering innovation in automotive technology.

2. Literature Review:

- Battery Management Systems (BMS) play a crucial role in ensuring the optimal performance, safety, and longevity of rechargeable battery systems. These systems, which combine both hardware and software components, are designed to monitor, control, and safeguard battery cells against potential risks such as overcharging, over-discharging, and thermal runaway [1]
- The emergence of Internet of Things (IoT) technology has led to the development of advanced Battery Monitoring Systems, offering features like real-time monitoring, remote accessibility, and predictive analytics. It underscores the advantages of IoT-based solutions in enhancing operational efficiency, minimizing downtime, and streamlining maintenance schedules, particularly in industrial settings [2]
- Among the platforms utilized for implementing battery monitoring and management systems, the ThingSpeak IoT platform has gained popularity due to its user-friendly interface, scalability, and comprehensive features. Researches look into the capabilities of ThingSpeak in facilitating real-time data collection, analysis, and visualization for various IoT applications, including environmental monitoring and smart agriculture [3]
- Wireless Sensor Networks (WSNs) have become an increasingly popular option for battery monitoring systems due to their capacity to enable wireless data transfer and remote surveillance. In 2019, Gupta et al. did research that explores the use of WSNs for monitoring several battery properties, such as voltage, current, and temperature. Their results demonstrate the effectiveness of WSNs in boosting battery monitoring operating efficiency and dependability, highlighting the technology's potential to improve battery management systems.[4]
- Machine learning techniques have been the focus of recent research to help with anomaly identification, problem diagnosis, and predictive maintenance in battery management systems. In this field of study, Liu et al. (2021) have investigated the application of machine learning methods such as artificial neural networks (ANN) and support vector machines (SVM) for the prediction of lithium-ion battery performance and residual usable life (RUL). This integration demonstrates how machine learning can be used to improve battery management systems by offering precise forecasts and insights for better maintenance plans.[5]
- The ThingSpeak platform, IoT technologies, and current battery management methods are all integrated into the proposed model. Using a microcontroller such as the ESP32 and sensor interface, the system collects data in instantaneous fashion from the battery system. To facilitate historical examination, trend identification, and information-driven choices for optimization and maintenance, the system records battery metrics on the ThingSpeak cloud server.

Table 1- Comparison between existing methods [1],[2],[3],[4] & [5]

Focus	Methodology	Application
Battery management systems for large lithium-ion battery packs.	Likely provides a comprehensive overview of BMS architecture, algorithms, and safety considerations.	Primarily targeted towards large-scale energy storage systems and electric vehicles.
IoT-enabled battery	Discusses the integration of IoT	Aimed at industrial settings

management system from an industrial perspective.	technologies for remote monitoring and predictive maintenance.	where real-time monitoring and maintenance of battery systems are crucial.
Real-time data acquisition and monitoring system using ThingSpeak IoT platform.	Describes the implementation of wireless sensor networks and cloud-based data storage for real-time monitoring.	Suitable for applications requiring remote monitoring and data analysis, such as renewable energy systems or smart grids.
Capacity fade of lithium-ion cells cycled at elevated temperatures**.**	Investigates capacity fade in lithium-ion cells under different cycling conditions and temperatures.	Provides insights into battery degradation mechanisms, relevant for battery performance evaluation and lifetime estimation.

3. Methodology

3.1 Battery charging

- Use an adapter to reduce the voltage levels required by the battery
- The output of adapter is fed to the converter
- The rectifier converts the 12V dc voltage to 5Vdc, required for equipments such as sensors, relays.

3.2 Battery pack design

- Lithium-ion battery of 3.7V and 2000mAH is used
- Three such single units are connected in series to obtain 11.1V
- The BMS board is connected to the battery pack.

3.3 Integration of sensors:

- Current sensor ACS712 is connected to the battery pack to monitor the charging and discharging currents
- DC Voltage sensor module is connected across terminals of battery pack
- DHT sensor is connected to monitor the temperatures of the battery pack

3.4 ThingSpeak server setup using ESP32

- Create a ThingSpeak account and then create a channel
- Obtain ThingSpeak API key
- Setup ESP32 board to computer

3.5 Arduino IDE Installation

- To begin, open the Arduino IDE and start a new sketch. include the necessary libraries, such as ‘WiFi.h’ and ‘HTTPClient.h’
- Set up your WiFi credentials within the sketch use the ThingSpeak API key to authenticate your requests to the ThingSpeak platform.

3.6 Software development:

- Write code to read sensor data from your ESP32 board.
- It involves interfacing with sensors connected to the ESP32 and retrieving sensor readings such as temperature, humidity, or any other relevant data.
- Compile it and upload it to your ESP32 board using the Arduino IDE.

4.Battery Health Monitoring System

Using cloud-based monitoring, the proposed battery monitoring system captures vital functional characteristics like voltage, current, and the battery's internal temperature as well as the surrounding

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 5, No.6, May : 2024
air temperature while charging and discharging. The battery management system is critical to meeting the infrastructure's changing needs for charging, particularly from the standpoints of automakers, electricity suppliers, car owners, and charging service providers. The proposed system can give EV customers real-time information regarding temperature levels, battery health checks, and charging and discharging status through a dedicated interface. The system offers an ideal energy trading solution for all parties involved in smart battery management infrastructure, in addition to providing an implementation framework for electric vehicle users. The report also describes cloud-enabled tactics that let users monitor battery performance from a distance. In the event that any parameter above the safety zone's specified value, the system supplies inputs to the protection bias, enabling the monitoring circuits to actually disconnect the battery from the system.

4.1 Why Lithium-ion Battery

Of all the metals found in nature, lithium is the lightest and has the highest electrochemical potential as well as the highest energy density per weight. Rechargeable batteries with lithium as the anode may have exceptionally high voltage, exceptional capacity, and viscosity at a remarkably high energy level. But lithium is unstable by nature, particularly when it's charging.

The two most crucial factors influencing lithium-ion cell performance are operating temperature and voltage. If the cell is used outside of the safety zone, it may sustain irreversible damage. It is possible to charge the batteries above their rated voltage or drain them below the suggested voltage. This could cause the electrode to break quickly. Li-ion cells should have their working temperature carefully regulated since too high or too low of a temperature could harm the cell. Three categories could be used to classify temperature-related damages: thermal runway, high temperature operational impact, and low temperature operational impact.

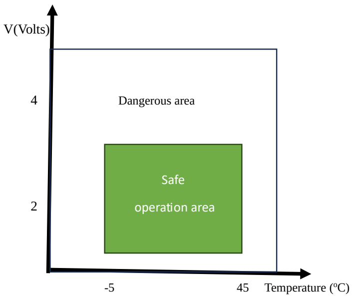


Fig:1 Voltage range of li-ion battery

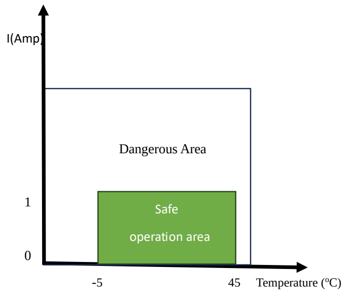


Fig:2 Current range of Li-ion battery

5. Architecture:

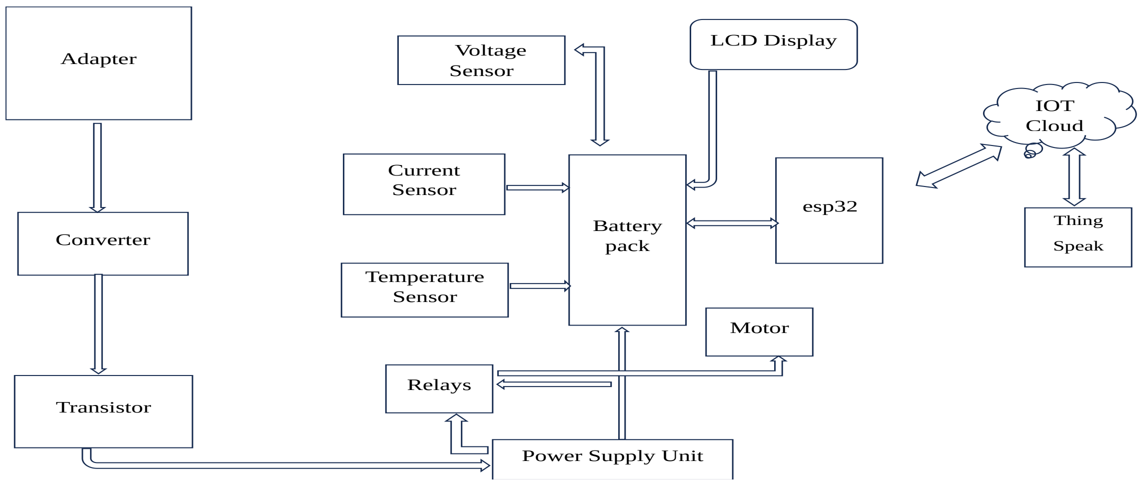


Fig 3: Schematic model of the battery health monitoring system

The block diagram illustrates the components of the system, including the ESP32 microcontroller, battery pack, motor, relays, sensors, and an LCD display. The ESP32 is the central control unit responsible for managing the entire system. The battery pack powers the system, while the motor, controlled by relays, simulates an electric vehicle's motor running at variable speeds. Sensors gather data such as temperature, voltage, and current, which is displayed in real-time on the LCD display, providing users with instant information about the battery's condition. Simultaneously, this data is continuously logged and recorded in the ThingSpeak application for further analysis and monitoring. Overall, the system integrates various components to create a functional setup that mimics the operation of an electric vehicle's motor while providing comprehensive monitoring and display of battery performance metrics.

6. Working

The battery charging mechanism is based on a rectifier's DC output, and charging current, voltage, and temperatures are monitored using Thingspeak. Similarly, during discharge, the system monitors discharging currents and temperatures. To quickly rectify any differences, relays are positioned carefully prepared to respond to variations in current and temperature. In the case of a short circuit, a specialized protection relay immediately isolates the circuit to ensure safety. Furthermore, to regulate temperature rises, a cooling fan operates automatically to cool the battery and prevent overheating. All relevant data about the battery pack is carefully kept on the Thingspeak server, allowing for real-time monitoring and analysis of any changes to the system, ensuring its smooth and efficient operation.

6.1 Components Description:

The hardware implementation is majorly through:

- **Esp32:**
  The ESP32, which replaces the ESP8266, comes in single- and dual-core versions and is equipped with Tensilica's 32-bit Xtensa LX6 CPU, which has integrated Bluetooth and Wi-Fi. Like the ESP8266, the ESP32 has integrated radio components, which is one of its significant advantages. These consist of an RF balun, filters, an antenna switch, a low-noise receive amplifier, and a power amplifier. This connection streamlines the development process overall by using fewer external components, which makes developing hardware around the ESP32 easier.

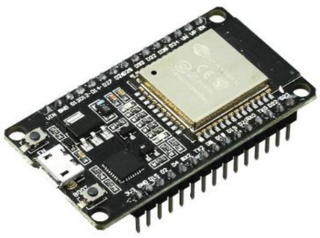


Fig 4. ESP 32

- **Current sensor**:
  Current sensor reports the charging and discharging cycles of battery and they help us to know how much energy we use. It also used to avoid over currents. Electric vehicle current sensors include resistive or magnetic elements based on their structure.

Fig 5. Current Sensor

Voltage sensor:

It is a tool for determining an electric circuit's voltage. The voltage sensor is also in charge of the vehicle's ideal speed and makes sure that it is adjusted as necessary. It constantly tracks and examines the battery state and lookimg for overvoltage or other problems.

Fig 6. Voltage sensor

- **Temperature monitoring sensor:**

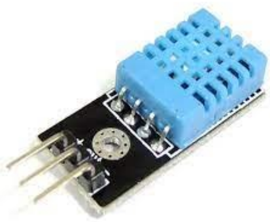


Fig 7. dht temperature and humidity level senor

It continuously measures the battery's condition and temperature. It aids in regulating the battery's operating condition and guards against overheating. In extreme condition it helps to prevent events such as battery meltdowns.

- **Li-ion 2000mah:**

Rechargeable lithium-ion batteries are frequently found in a wide range of electrical gadgets such as smartphones, laptops, and tablets. "2000mAh" refers to the battery's capacity, which stands for milliampere-hour. A 2000mAh battery can provide a current of 2000 milliamperes for one hour, or 1000 milliamperes for two hours, and so forth.

Fig 8. Li - ion Battery

The capacity of a battery is a critical factor in determining how long a device can operate on a single charge. However, other factors such as the device's power consumption and efficiency also play significant roles in determining actual usage time.

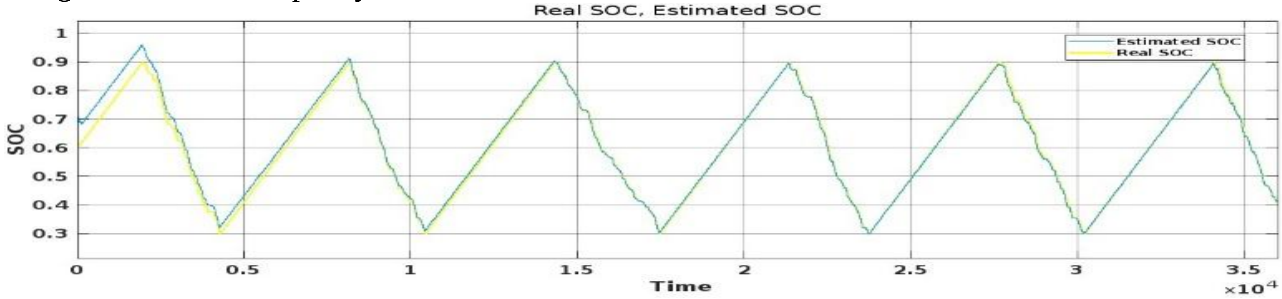
7.Functionalities

7.1 State of charge (SOC):

The possibility of a rechargeable battery having the maximum possible charge is known as state of charge, or SOC. A rate that varies from 0% to 100% is used to describe the charge level. The user can determine which resources are available and when the battery needs to be recharged by seeing the charge status indicator. State of charge (SOC) and battery life are very similar concepts. SOC can be calculated as the ratio of battery capacity left to the rated or maximum capacity given by the manufacturer. Monitoring the battery's level of charge is one of the BMS's functions. In addition to

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 5, No.6, May : 2024

controlling charging and discharging, the SOC may make gestures to the user. The factors including voltage, current, and capacity that are used to calculate SOC.



9. estimation of state of charge

7.2. State of Health (SOH):

The term "state of health" (SOH) refers to a metric that compares a battery's overall health to that of a new battery and indicates how well it can operate. Poor SOH batteries discharge far more quickly than good batteries. This is the outcome of the rated capacity declining. All of these can be used as assessment standards to choose SOH battery management solutions. A precise assessment of battery health can help identify battery deterioration early on and indicate when a new battery is needed. After SOH is acquired, we may access helpful data about the battery's performance as well as the whole energy storage system's dependability and efficiency. Thus SOH represents the performance of the battery compared to its once and anticipated future.

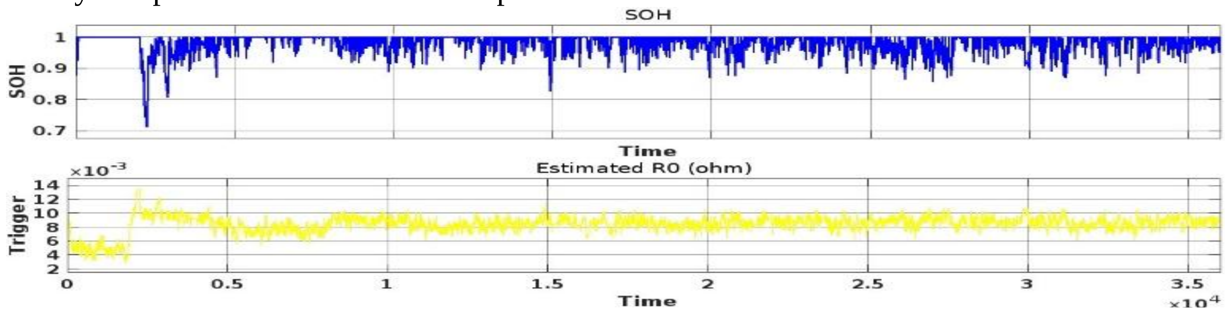


Fig 10. estimation of state of health

7.3. Current monitoring

To ascertain the battery pack's level of charge, the BMS keeps an eye on its voltage and charging current. Based on the SOC data, the BMS controls the method of charge by balancing the voltage and current to avoid excessive charging and heating up. In order to prevent any cell from being overcharged, the BMS also makes sure that each cell in the battery pack is balanced, or charged to the same voltage position. Voltage controllers and current detectors are employed in charge monitoring system. When the current detector is linked to IoT cloud, it detects current that is taken from the battery. The purpose of the voltage detectors is to monitor voltage and regulate the amount of current that can be supplied to the battery during charging.

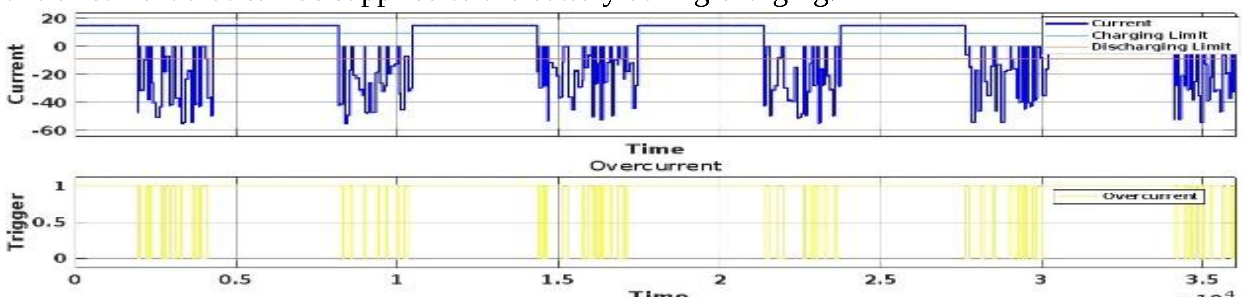


Fig 11. Estimation of over current

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 5, No.6, May : 2024

7.4. Temperature*:*

The model continuously monitors the variations in temperatures of the battery pack. If any deviations occur continuously, the system would take an action by implementing the cooling system. However, the BMS can spark admonitions, dissociate the battery pack from the system, if the temperature reaches a critical position. If the temperature rises above the critical value, a buzzer rings indicating there is a need to turn off system protecting from any fire accidents that might occur.

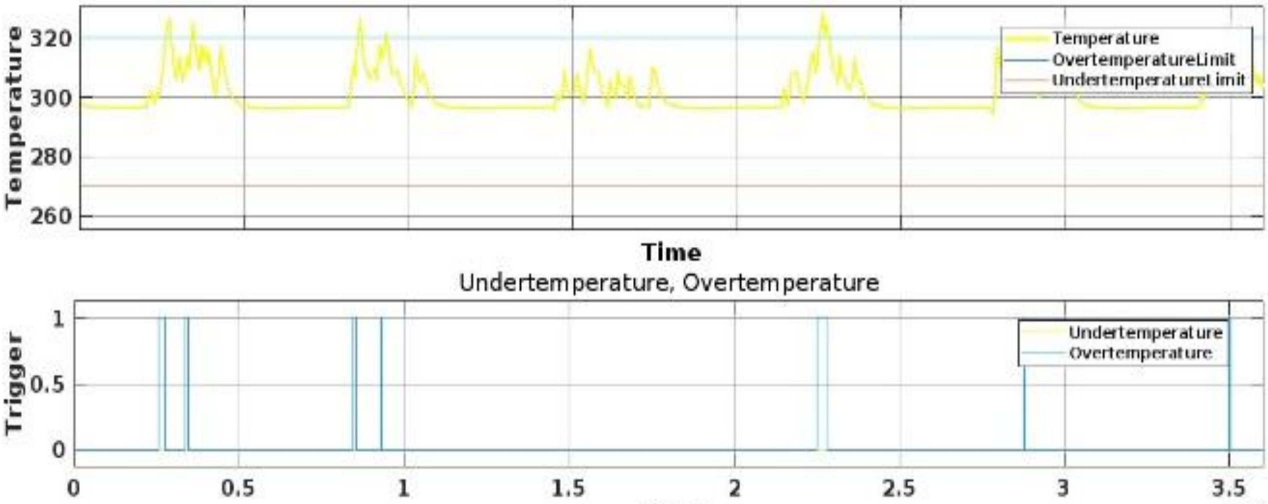


Fig 12. Temperature estimation

7.5. Protection against Short Circuits:

The proposed model of battery health monitoring system also checks for any short circuits that might occur across motor terminals. In cases of short circuit, it immediately senses the overcurrent due to short circuit and sends a signal to the relay. Hence the system can be isolated and hence well protected.

7.6. Cooling:

Heat is generated during charging and discharging process. Cooling systems are essential to maintain optimal temperatures for colorful factors, including the battery. Air inflow generated by the fan helps dissipate heat from these factors, contributing to overall thermal regulation.

8. Result

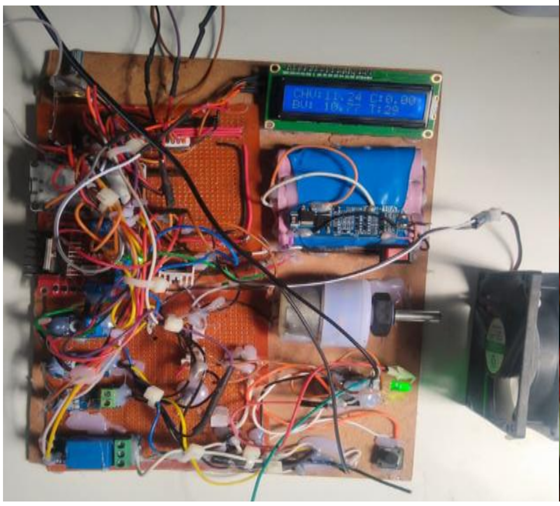
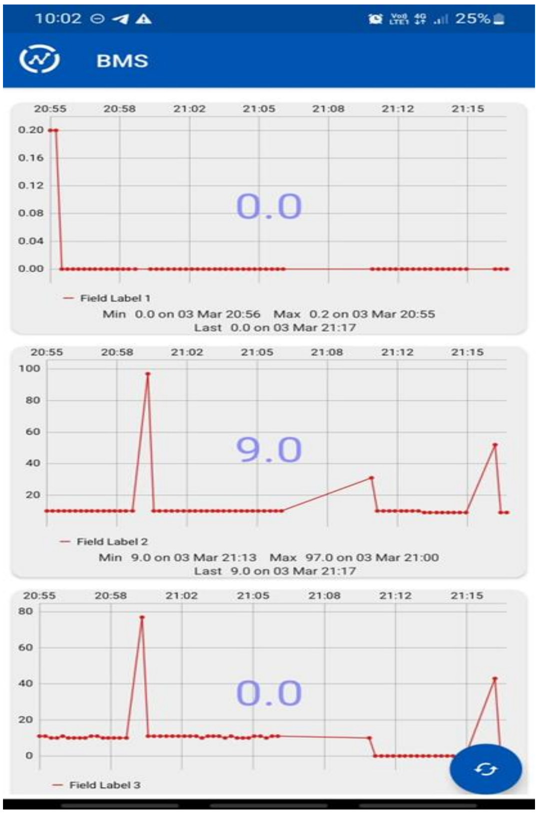


Fig 13. Hardware model of the system

Fig 14: LCD Display of various parameters



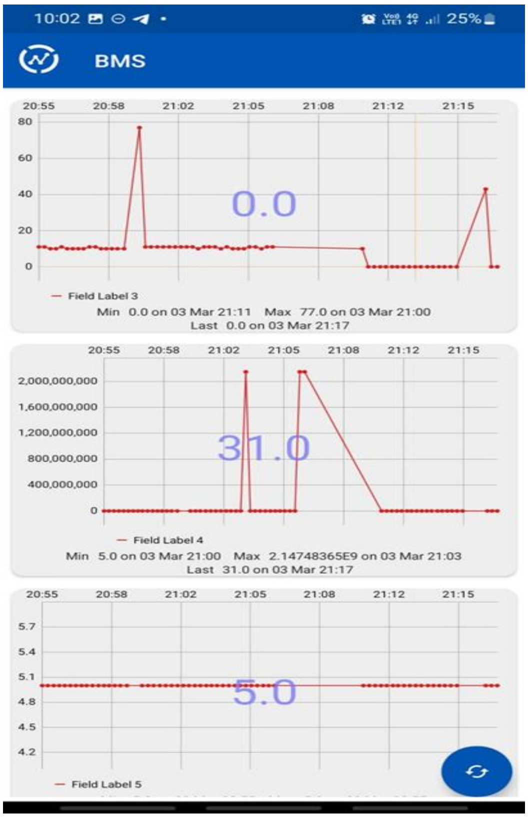


Fig 15 and Fig 16 User interface of Thingspeak

The developed battery system has been engineered with sophisticated capabilities to detect various critical parameters such as overvoltage, excessive currents, and abnormal temperatures. These functionalities are crucial for ensuring the safety and optimal performance of the battery pack. By continuously monitoring these parameters, the system can swiftly respond to any deviations or abnormalities, thereby mitigating potential risks and ensuring the longevity of the battery.

One of the key strengths of the system lies in its integration of multiple sensors and microcontrollers. These components work in tandem to gather real-time data from the battery pack and its surrounding environment. For instance, in the event of an overvoltage or excessive current, the microcontrollers can trigger protective measures such as disconnecting the battery from the load or activating safety mechanisms to prevent damage.

Furthermore, the system provides valuable insights into the battery's performance through its user interface components. An LCD display integrated into the system offers real-time visualization of the battery's present conditions, allowing users to monitor vital parameters at a glance. This feature enhances user awareness and facilitates prompt decision-making in response to any detected anomalies.

In addition to real-time monitoring, the system leverages the capabilities of ThingSpeak, an IoT platform, to store and analyze historical data. ThingSpeak serves as a centralized repository for storing past performance data of the battery system. By accessing this historical data, users can gain valuable insights into the battery's long-term behavior, identify patterns or trends, and make informed decisions regarding maintenance and optimization strategies.

Overall, the developed battery system represents a successful solution that offers robust performance, advanced monitoring capabilities, and seamless integration with existing systems. Its ability to detect and respond to critical parameters, coupled with its user-friendly interface and data analysis features, makes it an ideal choice for ensuring the longevity and optimal performance of battery systems in various applications.

9. Limitations

1. Limited Scalability: The system's ability to scale may be constrained by the capacity and functionalities of the selected IoT platform, like ThingSpeak. When the number of batteries being monitored or the volume of data points grows, scalability challenges might emerge. This could require system upgrades or transitioning to more scalable platforms to accommodate the increasing demands effectively.
2. Security Concerns: Sending sensitive battery health data over the internet raises security concerns, including the risk of data breaches and unauthorized access to confidential information. To address these risks, robust encryption and security measures must be implemented to safeguard the transmission and storage of data. These measures are essential to mitigate the potential for unauthorized interception or access to sensitive information, ensuring the confidentiality and integrity of battery health data throughout its transmission and storage.
3. Internet Connectivity: The system's ability to work depends on reliable internet access to send data to the ThingSpeak server. Processes for data collection and continuous tracking may be hampered by outages or disruptions in internet access. Due to this reliance on internet access, it may become more difficult to sustain uninterrupted and error-free operations, especially in locations where network disruptions are common. To lessen the negative effects of interruptions in internet connectivity on the functionality and dependability of the system, alternative tactics or backup plans could be required.
4. Complexity: The system's implementation can be complicated as it involves configuring several different parts, including sensors, microcontrollers, and Internet of Things platforms. Users with little technical experience may find this procedure difficult, especially during setup and maintenance. Streamlining setup processes and offering approachable manuals can assist in resolving these issues and improving system accessibility.

Conclusion

In conclusion, the Battery Protection and Health Monitoring System using ThingSpeak server represents a powerful solution for monitoring, protecting, and optimizing rechargeable battery systems across various applications. By leveraging IoT technology and cloud-based infrastructure, the system enables real-time monitoring, remote accessibility, and proactive management of critical battery parameters.

Throughout this system, users benefit from advantages such as real-time monitoring, remote accessibility, data logging and analysis, alerting mechanisms, enhanced safety, optimization of battery usage, and integration with the ThingSpeak IoT platform. These features empower users to make informed decisions, optimize battery performance, and extend battery lifespan while minimizing risks and maximizing operational efficiency.

References:

[1]. Heng, R., David, W., Pecht, M. (2017). Battery Management Systems for Large Lithium-Ion Battery Packs. John Wiley & Sons.

[2]. Das, S., Chatterjee, S., Mukherjee, S., Sarkar, S., Misra, S. (2018). Internet of Things (IoT) Enabled Battery Management System: An Industrial Perspective. IEEE Transactions on Industrial Informatics, 14(2), 720-729.

[3]. Mukherjee, S., Chattopadhyay, A., Misra, S., Nasipuri, M., & Jana, P. K. (2020). ThingSpeak based real time data acquisition and monitoring system. 2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT), 1-6.

[4]. Gupta, R., Rai, N., Mishra, P., & Pandey, B. (2019). Wireless Sensor Networks for Battery Monitoring: A Review. Procedia Computer Science, 165, 535-543.

[5]. Ramadass, P., Haran, B., White, R., & Popov, B. N. (2013). Capacity fade of Sony 18650 cells cycled at elevated temperatures: Part I. Cycling performance. Journal of Power Sources, 113-120.

[6]. Liu, J., Wang, H., Cao, W., & Xie, S. (2021). Remaining Useful Life Prediction of Lithium-Ion Battery Based on Optimized Support Vector Machine and Artificial Neural Network Ensemble Model. IEEE Access, 9, 17968-17981.
[7]Mr. Bowkett, K. Thanapalan, T. Stockley, M. Hathway, and J. Williams. "Design and implementation of an optimal battery management system for hybrid electric vehicles." In 2013 19th International Conference on Automation and Computing, pp. 1-5. IEEE, 2013.
[8] M.I. Karmawijaya, I. N. Haq, E. Leksono, and A. Widyotriatmo. "Development of big data analytics platform for electric vehicle battery management system." In 2019 6th international conference on electric vehicular technology (ICEVT), pp. 151-155. IEEE, 2019.
[9] J. Clairand, J. R. García, C. A. Bel, and P. P. Sarmiento. "A tariff system for electric vehicle smart charging to increase renewable energy sources use." In 2017 IEEE PES Innovative Smart Grid Technologies Conference-Latin America (ISGT Latin America), pp. 1-6. IEEE, 2017.
[10] H. Sayeed, M. N. Al Subri Ivan, H. Ratiqul, E. M. Mahjabeen, A. F. Saykot and C. A. Hossain, "Lead Acid Battery Monitoring and Charging System for Backup Generators," 2019 International Conference on Robotics,Electrical and Signal Processing Techniques (ICREST), Dhaka, Bangladesh, 2019, pp. 263-268, doi: 10.1109/ICREST.2019.8644475.
[11] K. Laadjal, and A. J. M. Cardoso. "Estimation of lithium-ion batteries state-condition in electric vehicle applications: issues and state of the art." Electronics 10, no. 13 (2021): 1588.
[12] Pelegov, V. Dmitry, and J. Pontes. "Main drivers of battery industry changes: Electric vehicles—A market overview." Batteries 4, no. 4 (2018): 65.