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Efficient Battery Monitoring System

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Abstract: This project seeks to create a new system that applies IoT technology to mitigate the issues associated with batteries today. It employs various crucial components: the ESP8266 microcontroller, ZMPT101B voltage sensor, ACS712 current sensor, DHT11 temperature sensor, and the RTC DS1307 module. These parts work together to determine the condition of the battery by obtaining accurate information with timestamps. This system is not limited to simply showing real-time data. It also makes it possible for users to see the health status of their battery via a mobile application or website, no matter where they are. It also sends instant alerts if there are any problems, including overvoltage, over current, overheating, or if the charge in the battery drops very low. All the data gathered is stored for future usage to support maintenance and make decisions effectively in the future. This battery management system is energy-saving, cost-reducing, and scalable, which makes it suitable for applications from small electric cars to big energy storage installations. The project has a detailed study that demonstrates the system is technically feasible, simple to use, and economically viable. Its architecture is future-proof, ready to accommodate artificial intelligence or machine learning for deeper analysis, allowing it to evolve with evolving smart energy technologies. Essentially, this project presents an end-to-end battery management solution that outpaces conventional boundaries, addressing the increasing demand for smart, networked battery management. With the inclusion of IoT features, data monitoring, remote diagnostics, and safety features, not only does it improve battery performance and dependability but also helps ensure sustainability targets for future electric transport and smart grids.

Keywords: Battery Management System, IoT, State of Charge, Predictive Maintenance, Remote Monitoring, Cloud Analytics, Electric Vehicles ,Battery Health Monitoring,

ABBREVIATIONS:

BMS	Battery Management System
IoT	Internet of Things
SoC	State of Charge
EV	Electric Vehicle
DC	Direct Current
AC	Alternating Current
ESP32	ESPressif Systems Microcontroller
MCU	Microcontroller Unit
RTOS	Real-Time Operating System
MQTT	Message Queuing Telemetry Transport
LCD	Liquid Crystal Display
AI	Artificial Intelligence
ML	Machine Learning
Wi-Fi	Wireless Fidelity
PCB	Printed Circuit Board
API	Application Programming Interface
IoE	Internet of Energy
GUI	Graphical User Interface
DoD	Depth of Discharge
GSM	Global System for Mobile Communication

I. INTRODUCTION

The global transition to electric vehicles depends on a reliable battery management system to guarantee safety, optimal performance, and long battery life. Traditional BMS solutions have limitations because they only provide basic charge protection and lack real-time analytics and remote monitoring capabilities. In order to provide accurate and time-stamped data logging, the intelligent IoT-based BMS described in this paper combines temperature, voltage, and current sensors with the RTCDS1307 module and ESP8266 microcontroller. The Blynk platform allows for real-time alerts and performance optimization, facilitating remote monitoring. The quick development of electric vehicles has raised the demand for effective battery management systems. The conventional battery management system only offers basic charge control and cannot prevent improper battery use, including deep discharge, overcharging, and temperature fluctuations.

II. EASE OF USE

This project's main goal is to develop a cutting-edge battery management system that allows for ongoing monitoring, optimizes battery performance, and extends battery lifespan. An RTC DS1307 module for time stamped data logging and the Blynk web server for real-time tracking are combined with internet of things (IoT)-based monitoring in the proposed system. The system provides proactive maintenance and prevents major battery failures by continuously monitoring battery parameters like voltage, current, and temperature. Through temperature control mechanisms, the BMS also helps maintain temperature ranges, preventing overheating or freezing of the battery, which could impair performance. The battery is protected from short circuits, overvoltage, and excessive heat by built-in protection features. Real-time system monitoring and optimization are made possible by interacting with external systems, such as car controllers or chargers. The intricate internal workings of this system are examined in this report, which also looks into its technological underpinnings, data analysis procedures, and user application capabilities. By continuously monitoring crucial parameters like voltage, current, and temperature, BMS ensures the safe and efficient operation of rechargeable batteries.

III. BACKGROUND

Batteries are essential parts of contemporary electrical and electronic systems and are used in electric vehicles, portable electronics, and renewable energy storage. Because of their long lifespan, low self-discharge, and high energy density, lithium-ion batteries are the most popular battery type. These benefits do, however, come with serious performance, safety, and maintenance issues.

A Battery Management System is essential to ensure the safe and efficient operation of rechargeable batteries. Its core functions include:

- Monitoring battery parameters such as voltage, current and temperature.
- Protecting the battery from unsafe operating conditions like overcharging, deep discharging, and overheating
- maintaining a balance of charge within individual cells to prevent imbalances and prolong lifespan.

Challenges of conventional BMS.

The majority of BMSs are constructed with preset thresholds and fixed rules. Reactive in nature, these systems react to errors after they occur rather than anticipating them. Reduced battery life, performance drops, and safety risks like thermal runaway or unscheduled shutdowns are usually the outcomes of this restriction.

Appearance of BMS.

The growing reliance on rechargeable batteries in vital applications such as industrial automation, portable electronics, renewable energy systems, and electric vehicles has accelerated the development of battery management systems. As energy storage has grown in significance in today's technological environment, ensuring battery systems are safe, dependable, and long-lasting has taken precedence. The growing need for battery management has led to the creation of sophisticated systems that can dynamically and effectively optimize battery usage in addition to monitoring battery health. Without automated control or real-time diagnostics, battery supervision in the early days of battery-powered systems was restricted to manual voltage and current checks. However, the shortcomings of this strategy, such as unanticipated battery failures, reduced energy efficiency, and possible safety hazards, highlighted the need for more sophisticated solutions. The need for comprehensive features, including fault detection, thermal management, charge/discharge regulation, and state-of-charge estimation, led to the development of battery management systems. Because lithium-ion batteries are more prone to overcharging, deep discharge, and temperature fluctuations, their introduction into high-demand applications increased the need for BMS. Lithium-based batteries are vulnerable to deterioration and safety risks like fire or thermal runways if improperly managed. Because it ensures that battery packs operate within safe electrical and thermal limits, BMS technology has consequently emerged as a critical component of EVs. Traditional building management systems have been transformed into intelligent, networked systems by recent advancements in microcontrollers, the internet of things (IoT), and cloud platforms. The lifespan and efficiency of batteries are greatly increased by these modern battery management systems, which now include real-time monitoring, remote access, cloud-based analytics, and predictive maintenance. Additionally, advanced diagnostics, anomaly detection, and life expectancy prediction are being made easier by the combination of artificial intelligence and machine learning.
By successfully addressing the problems of energy efficiency, operational safety, and system scalability, BMS represents a substantial shift from traditional battery monitoring to advanced battery management. Given the growing need for decentralized energy systems and electric mobility, BMS will remain essential in building the framework for future sustainable energy infrastructure.

IV. RELATEDWORK

Many research projects focus on improving battery management systems (BMS) for renewable energy sources and electric vehicles (EVs) by giving efficiency, safety, and dependability top priority.

Researchers are looking into methods like block chain for scheduling maintenance, machine learning for data analysis, and internet of things (IoT) technology for tracking. The major developments in smart building management systems are the main topic of this section. Senthilkumar and his group developed a novel way to monitor the batteries in electric cars. They used the Blynk platform in combination with cutting-edge technology, including an ESP8266 microcontroller and a DS1307 RTC module, to track the battery's condition in real time. Their solution sends alerts to enable timely maintenance by monitoring temperature, voltage, and current. However, setting up the system can be complicated and costly. Ananthraj and ArnabGhosh developed a battery management system (BMS) that uses sensors and an online database to track the health (soh) and state of charge (soc) of a battery. Although it depends on a dependable internet connection, this system is useful in places where real-time tracking is unavailable. An intelligent BMS that integrates fault detection, real-time data collection, and performance optimization through sophisticated algorithms was unveiled by Li Haiying and his team. Their system uses predictive tools and security measures to improve vehicle safety. However, it can be challenging to use in real-time situations because of the complex data analysis needed. A two-level comprehensive test system for hybrid electric vehicle batteries was proposed by Zhang and Zhang. Their invention accurately assesses performance by simulating different battery conditions. The disadvantage is that its widespread adoption is limited by the significant processing power and sophisticated infrastructure it requires. By combining deep learning and blockchain, Siyan Liu and his team have developed a novel approach for predicting battery longevity in the internet of vehicles (IoV). The system is frequently complex and costly to set up, even with its high degree of accuracy and security. The team led by Pavan Kumar focused on creating a battery management system (BMS) that can detect issues in real time while minimizing expenses. Their system lacks the sophisticated prediction capabilities of more costly alternatives; despite being designed to be safe and affordable for electric vehicles (EVs).To predict the health of lithium-ion batteries, RuiXiong and his colleagues created a method that uses Monte Carlo simulations and moving windows. Their approach is very reliable for real-time applications because it guarantees an exceptionally low error rate of less than 1.5%. However, it requires a significant amount of processing power and high-quality data. Other studies look into predicting temperature and evaluating battery deterioration by combining machine learning with physics-based models. For instance, YushengZheng and Mohammad Hanan's research demonstrates that these techniques produce precise results and a thorough understanding of battery performance, but they necessitate a significant amount of processing power and high-quality data.

Summary

In conclusion, new research highlights the increasing popularity of predictive, intelligent, and networked battery management systems. Blockchain and machine learning improve data security and prediction accuracy, while platforms such as Blynk offer remote access and smooth integration. Regrettably, a lot of current systems have problems with scalability, complexity, cost, or the need for reliable network infrastructure. By using affordable hardware, cloud-based real-time monitoring, and time stamped data logging, this project expands on earlier discoveries in an effort to strike a balance between cost and functionality while guaranteeing scalability and remote access.

V. RESEARCH METHODOLOGY

The project uses a clear-cut, open research methodology to create a battery management system (BMS) for the internet of things (IoT). It first identifies issues, then looks over previous research and creates the system. After that, the software and hardware are combined, and extensive testing and assessment are carried out to guarantee peak performance. This painstaking procedure contributes to the development of a reliable and efficient method for monitoring and protecting batteries, especially those found in energy storage devices and electric cars. Finding the requirements and difficulties with current BMS technologies was the main goal of the first investigation. Important features like real-time monitoring, remote problem diagnosis, timestamp-enabled data recording, and predictive maintenance needs are usually missed by traditional systems. Lack of these features leads to inefficiencies, shorter battery life, and more safety risks. This project intends to combine cloud and IoT technologies to create an advanced BMS in order to address these problems. Better battery setup monitoring, control, and safety features will result from this combination. A thorough review of earlier studies in this field offered insightful information about the most recent advancements in battery monitoring technology. This review looked at a number of methods, including block chain-based prediction models, internet of things (IoT)-based systems, and artificial intelligence (AI)-powered diagnostics. It highlighted areas that need more investigation and analysis and offered insightful information about the advantages and disadvantages of current systems. It also emphasized the growing need for systems that use real-time data and cloud analysis to efficiently monitor and manage battery health. The project moved into the system design phase after all the data had been gathered. Required hardware was selected, including an RTC DS1307 module for time-based data logging, a DHT11 temperature sensor, voltage and current sensors (ZMPT101B and ACS712), and an ESP8266 microcontroller for wireless communication. The software component programmed the microcontroller using the Arduino IDE, which had C/C++ embedded. Live battery information was displayed and accessible via web dashboards or smart phones using the BlynkIoT platform. To show how sensors, the microcontroller, and cloud servers communicate with one another, visual representations were made. Moved to a printed circuit board (PCB) in order to improve stability. Before each sensor was connected to the microcontroller, it was carefully adjusted and tested to make sure it worked. The ESP8266 device was set up to collect data from these sensors. It quickly sent this data to the Blynk cloud platform and used rules based on particular restrictions to decide what should be done. This setup made it simple for users to view and monitor data like temperature, voltage, and current from any location. A real-time clock (RTC) was used by the system to keep track of this data.C/C++ coding was crucial for handling and regulating sensor data during the software development phase.

Notifications for issues like excessive voltage, current, or overheating were sent by functions that were coded. In order to deactivate machinery when needed, programmable switches were installed. The Blynk dashboard was designed to ensure the system's security and efficient operation by displaying real-time data and sending automated alerts in urgent circumstances. Following setup, the system was put through a rigorous testing process in a variety of battery charging and discharging scenarios. Sensor accuracy, communication speed, alert response time, and system stability were among the variables used to assess performance. The results showed that the system managed battery-related tasks reliably and effectively. Accurate sensor data, real-time updates, and prompt notifications. The last phase involved evaluating and enhancing the system. We examined its communication speed, energy efficiency, and future growth potential. Enhancement opportunities were identified, including the use of machine learning algorithms to predict battery condition and the improvement of data analysis tools for future projects. In order to facilitate replication of the study and support future development efforts, we documented every step of the research process and collated the findings into an extensive technical report that included diagrams, tables, graphs, and code explanations. In conclusion, the research methodology used in this project provided a thorough and methodical way to address real-world battery management problems. The developed battery management system (BMS) offers an intelligent, economical, and scalable solution by fusing cloud platforms, embedded systems, and Internet of Things technology.

VI. EXPERIMENT

Our proposed system is intended to provide real-time battery health monitoring. It combines cloud-based software, small computer systems, and hardware sensors. Improving battery longevity, performance, and safety are the goals. Electric cars, renewable energy storage, and providing backup power in manufacturing facilities can all benefit from this.

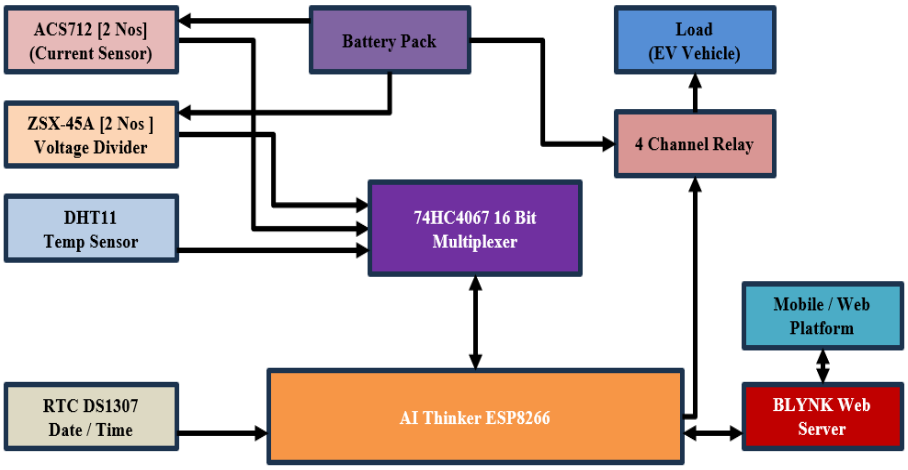

Fig1. Block Diagram of IoT-Based Battery Management System

A. Hardware Components

A microcontroller is connected to a variety of sensors and electronic components that make up the hardware component of this internet of things (IoT) battery management system (BMS). This setup ensures the battery operates at its best by allowing for continuous performance monitoring. In order to collect data, protect it, and enable wireless communication, each component is essential. The system is perfect for use in industrial battery applications, energy storage systems, and electric vehicles because it is compact, reasonably priced, and energy-efficient.

ESP8266 Microcontroller:

As the nodemcu, the ESP8266 microcontroller is the main part of the system. It's a small computer with wireless communication capabilities. It gathers, evaluates, and sends data to the BlynkIoT platform from sensors that measure temperature, voltage, and current. It is ideal for Internet of Things applications because it is wireless and doesn't require any additional network equipment.

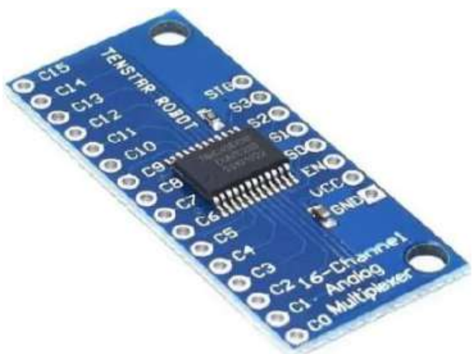

Fig 2. ESP8266 Microcontroller

Voltage Sensor (ZMPT101B): The zmpt101b sensor is employed to gauge the voltage of the battery as it fluctuates. It's highly accurate and safeguards the battery by preventing excessive voltage from reaching either extreme.

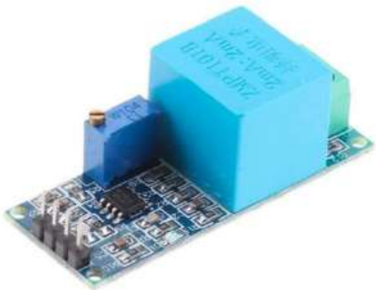

Fig 3. Voltage Sensor (ZMPT101B)

Current Sensor (ACS712 5A): The current sensor (acs712 5a) monitors the charging and discharging process of the battery. It employs the hall-effect principle to generate a voltage that aligns with the current flow. This feature helps identify if the current is too high and aids in efficient power control.

Fig 4. Current Sensor (ACS712 5A)

Temperature Sensor (DHT11): The dht11 is a temperature sensor that monitors the temperature near the battery and provides digital readings of both temperature and humidity. This data is crucial for preventing heat-related problems. If the temperature exceeds the predetermined thresholds, the system can initiate protective measures such as disconnecting the load or activating cooling mechanisms.

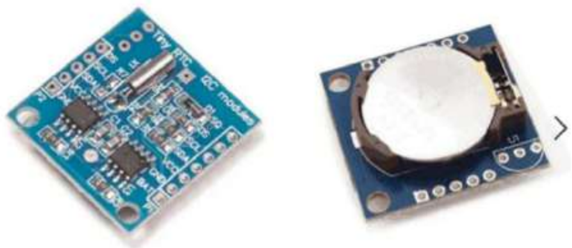

Fig 5. Temperature Sensor (DHT11)

Real-Time Clock (RTC) DS1307:

The RTC module in ds1307 guarantees that data is recorded with precise timestamps. This enables the tracking of the battery's performance over time, which is essential for comprehending when maintenance is required. Despite power outages, the RTC remains operational due to its integrated battery.

Fig 6.RTCDS1307

Relay Module: The relay module serves as an electronic switch, overseeing the connection between the battery and the load or charger. The microcontroller has the capability to disconnect the battery in order to improve safety and prolong its lifespan when circumstances such as overcharging, deep discharge, or overheating arise.Power Supply and Voltage Regulation: The ESP8266 and sensors rely on a consistent 5v power supply. A voltage regulator guarantees the smooth functioning of the system and protects it from voltage fluctuations. By employing specific techniques, we prevent electrical noise from interfering with sensor readings, guaranteeing their accuracy.

Fig 7. Relay Module

B. Software Components

Arduino IDE: When working with the ESP8266 microcontroller in your battery management system (BMS), the Arduino

Fig 8. Arduino IDE logo

IDE is a necessary tool. This tool makes it simple to write and upload C/C++ code directly to the microcontroller. In order to calculate the state-of-charge (soc) and evaluate the condition of the battery, the ESP8266 gathers vital data from sensors, including temperature, voltage, and current. In order to enable real-time monitoring and control, the Arduino ide also helps with the development of firmware that wirelessly connects to the BlynkIoT platform. This makes it possible to write and upload C/C++ code directly to the microcontroller.BlynkIoT Platform: In a battery management system (BMS), the BlynkIoT platform is crucial for real-time activity monitoring, clear data presentation, and remote alert sending. It ensures a flawless internet experience by acting as a link between the user and the ESP8266 microcontroller. With Blynk, users can effortlessly keep an eye on vital battery data, such as temperature, voltage, and current, through an intuitive mobile app or web dashboard. This cloud-based system ensures convenience and reliability by enabling users to easily access their battery data from any location. One notable feature of Blynk is its user-friendly dashboard, which makes it simple for users to alter their monitoring preferences. With the Blynk app or web interface, users can quickly and easily access battery level information through visual aids like gauges, indicators, and graphs, giving them a clear picture of the battery's condition. Blynk also makes it possible to store historical data, which is useful for monitoring performance patterns and learning about the long-term behavior of batteries both of which are essential for maintenance and early problem detection. Blynk's push notification system is one of its best features. When there is a problem such as an overvoltage, deep discharge, high temperature, or current fluctuation sit immediately alerts users. These alerts ensure that users are promptly aware of any possible battery issues by being sent straight to their email or mobile device. In order to facilitate proactive monitoring and improved battery protection, users can choose to set specific limits for these alerts.

Fig 9. BlynkIoT Platform logo

With Blynk, users can control their devices from anywhere. You can control different parts of your system from a distance. For example, you can use the Blynk app to turn on the cooling system or turn off specific parts if your system is overheating. By giving you more control, you can maximize the performance of your battery system.

The cloud-based setup offered by Blynk is a big plus. It speeds up communication and guarantees the safety of your data on the internet. Fast data transfer and timely responses are made possible by the ESP8266 microcontroller's wi-fi connection to the Blynk cloud. Blynk uses wireless technology, which makes setup easier, permits easy expansion, and helps keep costs under control, in contrast to systems that depend on wired connections. Microcontrollers can be programmed using embedded C/C++. You can work with hardware elements like sensors and communication protocols in the battery management system (BMS) using this programming language. You can create firmware that can read sensor data, analyze it (for example, to determine battery level), and communicate with Blynk by using embedded C/C++. These languages guarantee the BMS runs effectively because they are excellent at managing memory, processing data quickly, and interacting directly with hardware.For wireless data transmission and remote BMS access, cloud communication protocols are essential. The ESP8266 can connect to platforms such as the BlynkIoT or send data to the cloud thanks to these protocols. MQTT and http are popular protocols for effective data transfer between devices and servers. As long as you have an internet connection, you can easily monitor and manage your battery system from anywhere by adhering to these protocols. This enables you to closely monitor the situation and quickly address any issues that may come up.

C. Components Required

Table 1. Required Components

S. No.	Component	Quantity
1	ESP32 Microcontroller	1
2	Lithium-ion Battery (18650)	1
3	Voltage Sensor (ZMPT101B)	1
4	Current Sensor (ACS712)	1
5	Temperature Sensor (DHT11)	1

VIII. SYSTEM IMPLEMENTATION

Because it converts the planned design into a functional model, the system implementation phase is essential. In this phase, we assemble hardware, set up the system, create software modules, and connect hardware and software. The main goal is to ensure that the system performs as planned, satisfies the requirements, and works effectively in various situations. We take a methodical approach, starting with hardware component setup, moving on to software development, and finishing with system integration. To ensure flawless operation, accurate results, and ongoing monitoring, we carry out a number of tests. In the end, this stage ensures that the system is completely operational, optimized, and ready for use.

A. HARDWARE IMPLEMENTATION

To ensure effective monitoring and control, the battery management system integrates essential hardware components and makes use of IoT (internet of things) technology. As the primary processing unit, the ESP8266/ESP32 microcontroller oversees data collection and makes cloud communication easier. A rechargeable battery pack serves as the power source, and its optimal performance is continuously checked for voltage, current, and temperature.For long-term battery health monitoring, the system has a real-time clock module (ds1307) that logs timestamps. While the ACS712 (5A) current sensor evaluates the current flow, the zmpt101b voltage sensor continuously checks voltage levels. By continuously monitoring variations in battery temperature, a temperature sensor (DHT11 or DS18B20) ensures safety. A relay module manages the charging and discharging processes to control the power flow and prevent the battery from being overcharged or deeply discharged. Additionally, by maintaining constant voltage and current levels, a power management circuit protects the battery and its associated components. The smart IoT-enabled battery management system (BMS) increases battery lifespan, safety, and efficiency by integrating these components.

Circuit Assembly

As shown in figure 10, the sensors were successful in connecting to the ESP8266/ESP32 microcontroller.

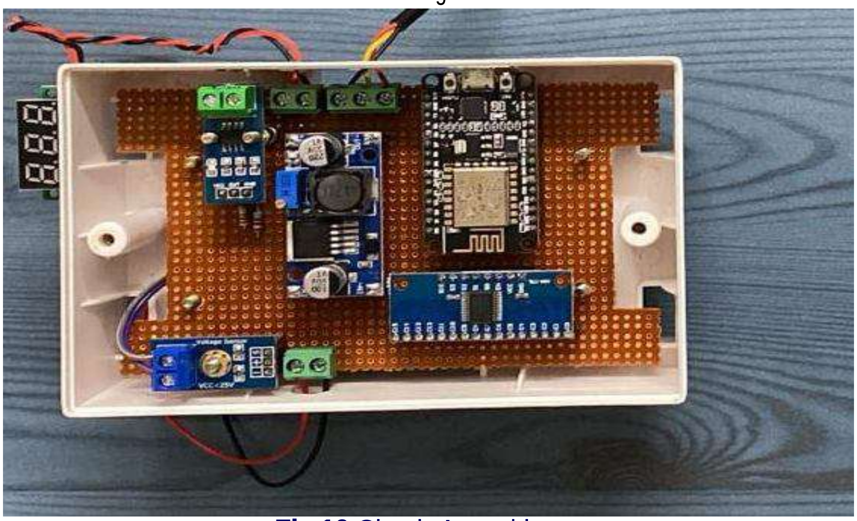

Fig 10. Circuit Assembly

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To guarantee a consistent power supply for every device, a power management system was put in place. To connect the sensors to the data storage, we used I2C, SPI, and UART communication methods. Initial testing confirmed that everything worked as it should.To ensure smooth operation, ongoing monitoring, data logging, and control, the sophisticated battery monitoring system is painstakingly put together. The ESP8266/ESP32 microcontroller, which gathers data from all of the connected sensors, is the circuit's primary component. The primary power source and the primary focus of monitoring is a rechargeable 12v battery pack.

To quantify essential variables:

- AZMPT101Bvoltage sensor continuously monitors the battery's voltage
- An ACS712 5a current sensor measures the current flowing in or out of the battery
- A temperature sensor (DHT11 or DS18B20) is placed near the battery to detect any temperature rise, ensuring it stays safe from overheating. To record time-stamped battery status data, the RTC module (DS1307) is connected to the microcontroller via I2C pins. This facilitates the analysis of historical data and the identification of performance trends. To control the battery's charging and discharging, the relay module is connected to the ESP8266/ESP32's control pin. It acts as the control mechanism that allows the microcontroller to cut off the load in the event that it detects deep discharge, high temperature, or overcurrent. Specific MCU pins are connected to each sensor input. Because of its integrated wi-fi, the ESP module can easily connect to the Blynk app and send data in real time to a cloud server. After that, this data is displayed for instant access on a web or mobile interface. Information is instantly available without the use of an app thanks to a nearby digital display that shows the current voltage. All components are guaranteed a constant voltage by the power management circuit, protecting them from sudden variations that could cause damage. To avoid interference, the setup is put together on a PCB or breadboard with clean wiring. During testing, the circuit can be powered via a USB connection or directly from the battery with regulation.

B. SOFTWARE IMPLEMENTATION

The software for the Internet of Things' (IoT) Battery Monitoring System (BMS) is developed using a specific configuration. Writing C/C++ programs for a device known as the ESP8266/ESP32 microcontroller is part of this setup. These programs are built with the aid of tools such as Platform IO and the Arduino IDE. Through a service called Blynk, the system establishes a connection to the cloud, ensuring real-time communication. This makes it possible for the sensors on your hardware to send data to a cloud dashboard continuously. This makes it simple for you to monitor the system, manage it as necessary, and get notifications when something needs your attention. Programming Language (C / C++): C/C++ was used to develop the firmware, which allows us to directly control the microcontroller's components and guarantees that the sensors and communication modules function properly together. Development Platform (Arduino IDE): The Arduino ide, which provides a simple interface for writing, compiling, and uploading code to the ESP8266/ESP32 boards, was used to create the project, as shown in Figure 11. Additionally, the concept encourages ongoing monitoring and debugging, both of which were essential throughout the development and testing stages.

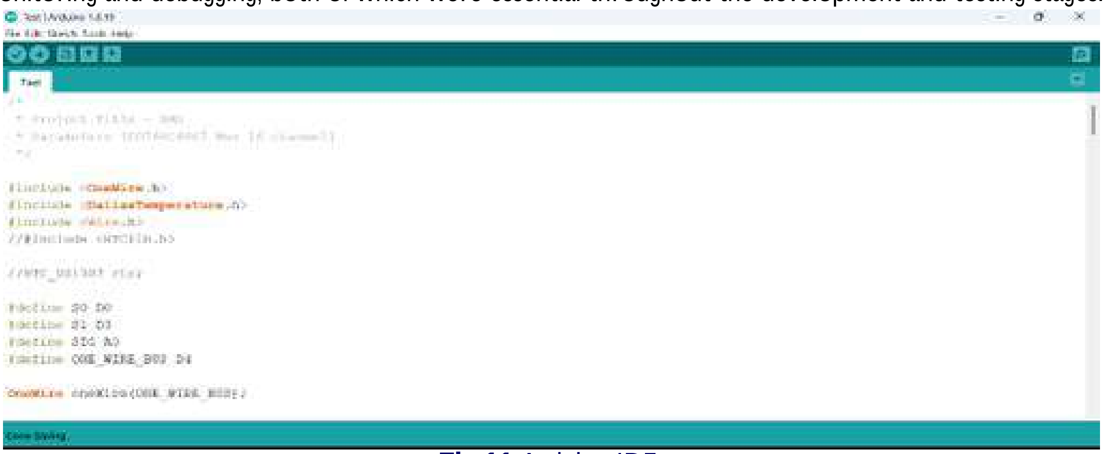

Fig 11. Arduino IDE

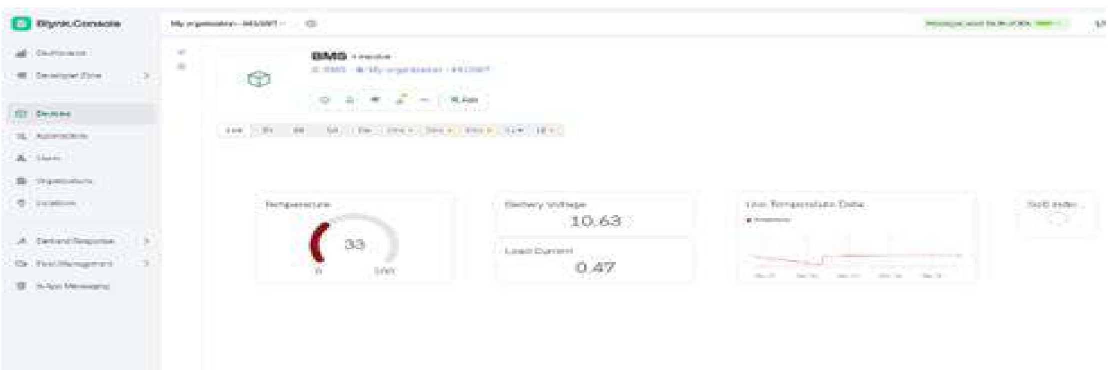

Fig 12. BlynkWeb Dashboard

Cloud Platform: Figure 12 was used by the Blynk web server for cloud-based control and visualization. In addition to interactive elements like buttons, graphs, and notification triggers, it provided a real-time display of sensor data. Additionally, it guaranteed seamless communication between the hardware, web dashboard, and mobile app.

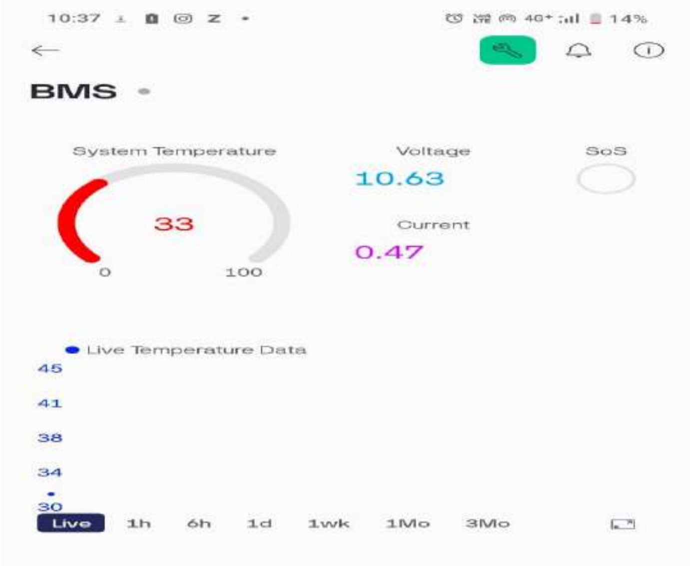

Fig13. BlynkMobile App Dashboard

C. REMOTE MONITORING AND ALERTS

One of the project's significant advancements is the integration with the Blynk platform, which serves as a cloud-based dashboard for remote monitoring. This platform enables users to:

- Visualize real-time data using gauges, charts, and numeric displays.
- Configure custom thresholds for voltage, current, and temperature metrics.
- Receive push notifications or email alerts when any anomaly is detected (e.g., battery overheating, overcharging, deep discharge), allowing users to take timely corrective actions.

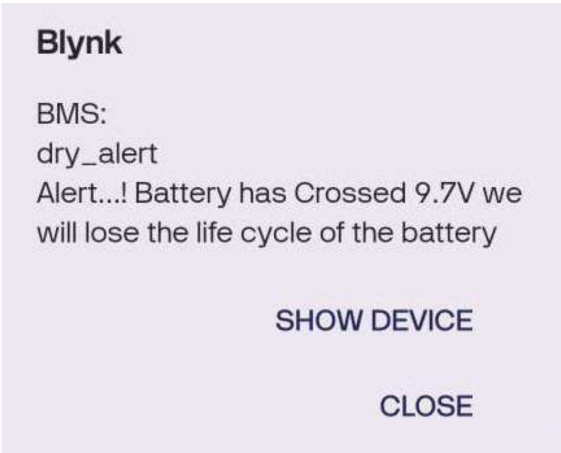

Fig 14. Dry SoS Indication on Dashboard

The dry running alert, shown in Figure 14, is triggered when the battery discharges further after its voltage drops below a critical level. Dry running is a condition that can shorten the battery's lifespan and negatively affect its health. By keeping an eye on voltage levels, the system detects this anomaly and immediately notifies the user through the Blynk dashboard, urging them to take precautions and prevent further damage. The deep running alert, which occurs when the battery is discharged to a level greater than its recommended depth of discharge, is shown in Figure 15. Deep discharging shortens the battery's life and increases the possibility of irreversible chemical changes in the battery cells. In order to protect the battery, the system can automatically disconnect the load using a relay and display a warning on the dashboard when a particular condition is detected. When the temperature sensor senses that the battery is getting too hot, it triggers the temperature alert, which is shown in Figure 16. Thermal runaway, which can be very dangerous, can be caused by high temperatures. The system responds quickly by informing the user via the dashboard and possibly taking preventative action. These safety-oriented features, which ensure that the battery operates within safe bounds, are essential parts of the software implementation. Together, they increase the system's dependability, guarantee user safety, and advance the batteries' long-term sustainability through prompt and wise decision-making and management. The smart alert mechanism, which is a component of the automated email notification system, is made to automatically send emails when the battery reaches a critical condition. Regardless of whether the user is actively using the Blynk app or dashboard, these notifications ensure that they receive real-time updates.

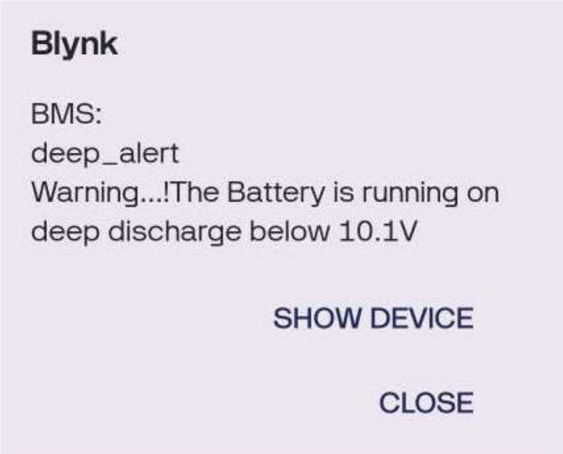

Fig15. Deep SS Indication on Dashboard

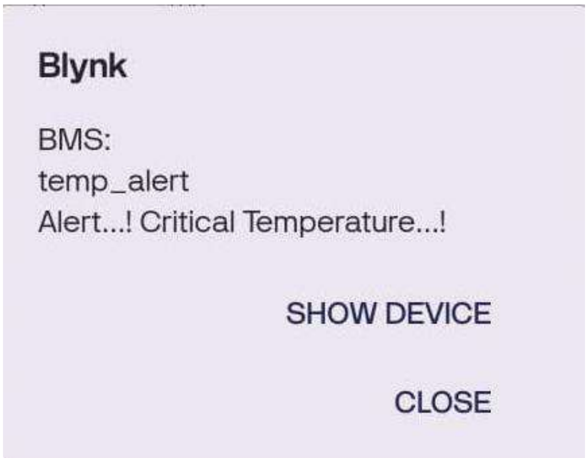

Fig 16. Temp SoS Indication on Dashboard

The system detects dry running when the battery's voltage drops below a certain threshold and continues to discharge. This can reduce overall efficiency and damage battery cells. The user is promptly notified of the issue by a pre-configured email sent by the integrated ESP8266/ESP32, which is connected to the Blynk platform. The email describes the nature of the problem and often suggests quick fixes, like stopping use or starting a recharge, to stop additional damage. The email notification is shown in Figure 17.

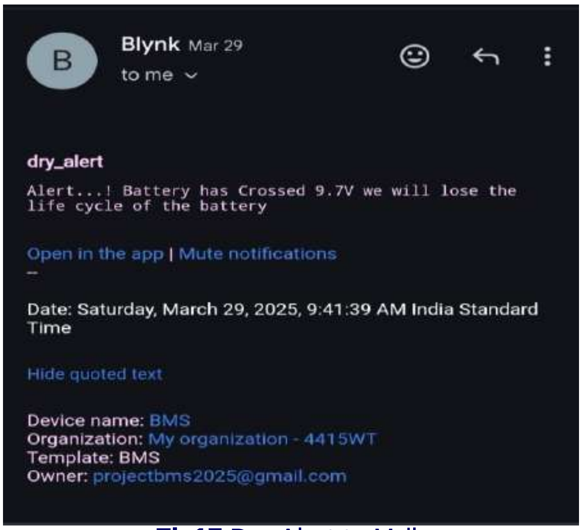

Fig17. Dry Alert to Mail

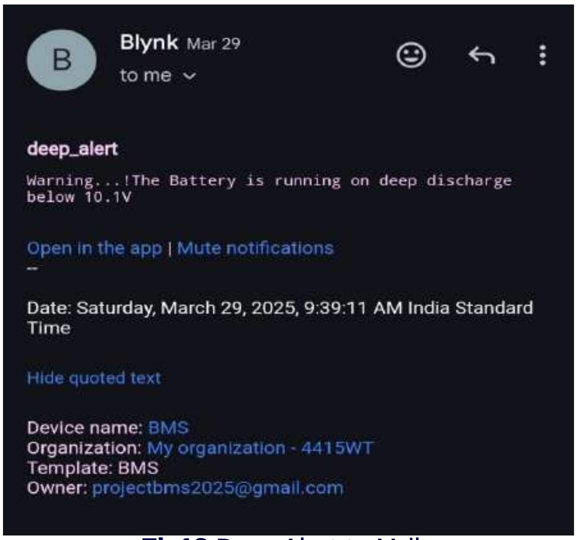

Fig18. Deep Alert to Mail

Deep discharge, which can drastically reduce a battery's lifespan and cause irreversible cell damage, occurs when the battery is depleted to an unsafely low level. The user receives a real-time email alert from the system as soon as voltage thresholds are detected, allowing them to take immediate action, such as disconnecting the load or starting a safe recharging process. When it comes to electric vehicles, this warning is crucial because a large discharge could cause the vehicle to malfunction. The deep discharge email is shown in Figure 18.

Fig19. Temp Alert to Mail

The system instantly sends an email notification if the temperature sensor (DHT11 or DS18B20) determines that the battery is becoming too hot above a predetermined safety threshold. Hazardous conditions like thermal runaway or battery swelling can be brought on by excessive heat. This alert ensures that the user is informed even when they are not in contact with the system, allowing them to quickly resolve the problem by cooling the battery or turning it off from charging or use. The temperature alert email sent by the system is shown in Figure 19.

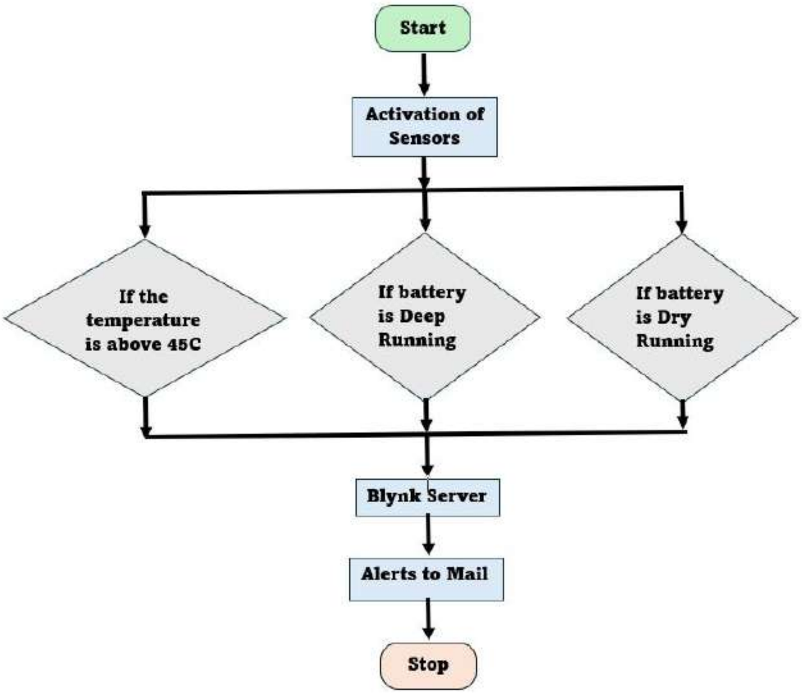

Fig 20. Data Flow Diagram

In addition to providing a responsive and user-centric IoT experience, these mail alert features expand the system's capabilities beyond real-time monitoring by guaranteeing user safety, preventive maintenance, and battery health protection. The given flowchart represents the monitoring and alert mechanism in an IoT-Based BMS.

VIII. RESULT

Highly encouraging outcomes from the implementation of the IoT-based battery management system showed its potential for safety assurance, anomaly detection, and real-time battery health monitoring. Critical battery parameters like voltage, current, and temperature could be continuously monitored thanks to the ESP8266/ESP32 microcontroller's integration with important sensors like the ZMPT101B voltage sensor, ACS712 current sensor, and DS18B20/DHT11 temperature sensor. The microcontroller's built-in wi-fi enabled it to handle sensor data efficiently and establish a real-time connection with the cloud. On both web and mobile dashboards, the Blynk platform offered an extensive and intuitive user interface. Users could set safety limits, view real-time sensor data, and receive immediate notifications. When overcharging, deep discharging, or overheating occurred, the system efficiently generated alerts that were shown on the dashboard and automatically sent as email notifications. By enabling users to respond quickly to potentially dangerous situations, these real-time alerts reduced the likelihood of battery failure or damage. By using relay controls to cut off the load, the system was able to identify and handle dry running and deep discharge scenarios during the testing phase.

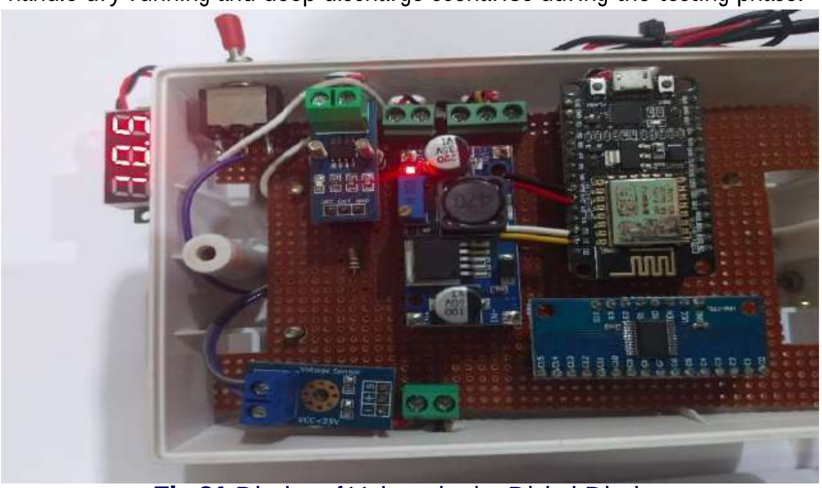

Fig 21. Display of Voltage in the Digital Display

When the battery temperature surpassed the preset safety thresholds, it also sent out alerts. The proactive alert system was very successful in enhancing operational safety and halting irreversible battery deterioration. Additionally, the data logging system made it possible to record time-stamped data, which made it easier to analyze historical performance and support proactive maintenance and well-informed decision-making. The system's high accuracy, responsiveness, and efficiency were validated by its consistent performance across various testing scenarios. It demonstrated the advantages of integrating IoT and machine learning technologies into modern energy management solutions in addition to improving battery safety and extending operational lifespan.

IX. APPLICATIONS

The designed system is versatile and scalable, making it suitable for various real-world use cases, including:

- **Electric Vehicles:** Continuous monitoring of battery systems in EV's ensures safe driving conditions and prolongs battery life.
- **Renewable Energy Systems:** Solar and wind energy storage solutions depend heavily on battery health.This system can help prevent downtime and optimize energy storage efficiency.
- **Industrial Battery Systems:** Factories and data centres often use battery banks for backup power. Real-time monitoring can prevent unexpected outages and ensure regulatory compliance.
- By providing real-time insights, predictive failure warnings, and cloud-based analytics, this system supports a proactive maintenance approach, reducing the total cost of ownership and enhancing the reliability of battery-dependent systems.

X. CONCLUSION

By creating a new battery management system, the project has accomplished a major objective. This system ensures that the battery is always accurately monitored by recording important battery parameters like voltage, current, and temperature. It logs data with timestamps using the RTC DS1307 module, allowing for the monitoring of battery performance and health over time. Users can view real-time data and access cloud-based monitoring from any location with the Blynk web server. The dashboard's ease of use makes it simple to monitor the battery's condition. In order to help avoid problems like overcharging, deep discharge, and dry running, the system also automatically sends out alerts and notifications. These warnings are essential for preserving the safety and health of the battery, preventing damage.By intelligently managing charge cycles and making efficient use of energy, the Battery Management System (BMS) prolongs battery life. This enhances battery performance and safety, particularly in electric cars where dependability is essential to a vehicle's lifespan. The project has illustrated the advantages of predictive maintenance using IoT-based battery monitoring. It is a major contributor to the development of smart battery systems in crucial fields by offering real-time insights, evaluating data, and proactively managing systems.

XI. FUTURE WORK

With much room for development, the Internet of Things-based battery management system provides a solid basis for sophisticated energy control. The system's capacity to anticipate battery issues and optimize energy use can be improved by incorporating artificial intelligence and machine learning. Because the ESP32 microcontroller has more input/output pins and more processing power than the ESP8266, it can add more capabilities. By decreasing downtime and providing greater convenience, an automated battery swapping system can greatly enhance the experience of driving an electric vehicle. The system's worth in the energy industry will rise if it is improved to function with different types of energy storage and electric car technologies. Creating a customized mobile application can enhance user access and control by enabling remote system management and real-time updates. A more thorough grasp of battery performance will be possible by extending the sensor network to incorporate measurements of pressure, humidity, and other environmental variables. Last but not least, enhancing the system's security is crucial to safeguard private information and stop illegal access, guaranteeing dependability and confidence in broad use.

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