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Iot Based Battery Monitoring System

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Abstract: In today's competitive industrial environment, batteries are essential for powering various types of equipment. They are predominantly used in grid systems and electric vehicles. To enhance the efficiency of battery operations and prolong their lifespan, and prevent them from reaching a destructive state, Battery Monitoring Systems (BMS) are employed in numerous industrial and commercial applications. The integration of BMS capabilities and its modularization is a fascinating and trending focus in current BMS research. Various monitoring techniques are implemented to assess the battery's State of Charge (SoC), temperature, and current levels. A prototype of a BMS has been developed to oversee these battery parameters. This BMS is designed using a microcontroller, sensors, and additional components like the ESP8266 PROCESSOR, temperature sensor, voltage sensor, and current sensor (ACS712).The system is capable of evaluating and displaying important metrics such as battery temperature, charging and discharging current, battery voltage, and SoC for the specified model battery. The battery data and the results emphasizing the primary characteristics of the system are displayed on the BLYNK screen..

Index Terms - Wireless power transmission, Solar roadways, Solar panel, Renewable energy

I. Introduction

A Battery Monitoring System (BMS) is an electronic system designed to oversee, manage, and safeguard a rechargeable battery. Its main purpose is to ensure the safe and effective operation of the battery, extend its lifespan, and prevent any harm to the battery and other system components. Battery Monitoring Systems (BMS) serve several important purposes like safety, performance, Reliability and cost-effectiveness, compliance.
A Battery Management System (BMS) usually includes a microcontroller, voltage regulators, current sensors, temperature sensors, and communication interfaces. The microcontroller is the main control unit, overseeing the voltage, current, and temperature levels of the battery and making decisions based on the information it gathers. Current sensors detect the flow of current into and out of the battery, whereas temperature sensors track the temperature of the battery. The communication interfaces enable the BMS to interact with other components of the system, like a charger or a load, and to convey status information to the user. The BMS usually comprises a microcontroller, voltage regulators, current sensors, temperature sensors, and communication interfaces. The microcontroller functions as the primary control unit, monitoring the voltage, current, and temperature of the battery and making decisions based on the information it receives. Current sensors measure the flow of current entering and exiting the battery, while temperature sensors keep track of the temperature of the battery. The communication interfaces assist communication between the BMS and other system components, such as a charger or a load, and provide relevant status updates to the user.

II. Methodology

The first step in the project is to set up the hardware, which involves connecting voltage, current, and temperature sensors to the GPIO pins of an ESP32 and supplying power to the device. After the hardware is set up, the focus shifts to firmware development. This includes installing either the Arduino IDE and writing code that reads sensor data for voltage, current, and temperature. The code will also process and filter this data to determine the State of Health (SoH) and State of Charge (SoC), and monitor charging and discharging currents and voltages over time. What's more, the processed data will be transmitted to a cloud platform for additional analysis. After finishing the firmware development, a mobile app will be used to enable wireless interaction. The Blynk application will be used to present real-time battery data, making it easy for users to monitor performance. Finally, a comprehensive testing phase for both the firmware and hardware setup will take place to ensure everything functions correctly. Once testing is finished, the ESP32 device will be put into operation alongside the battery, allowing users to continuously monitor data through the mobile app.

III. Block Diagram

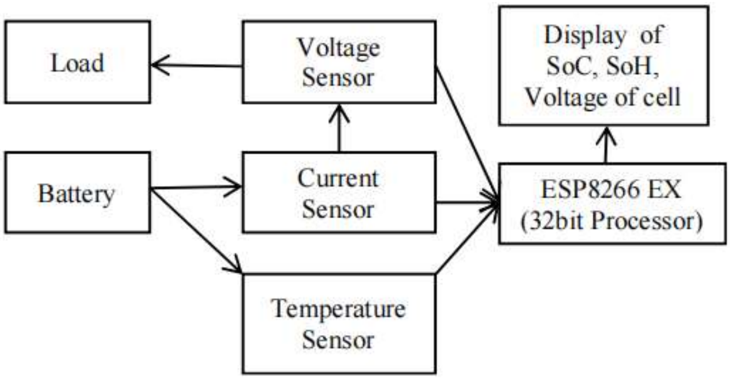

Fig.1. Block diagram of load side

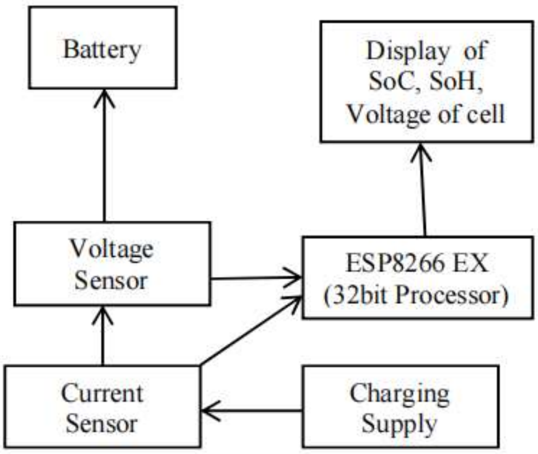

Fig.2. Block diagram of charging side

IV. Block Diagram Description

A battery monitoring system involves measuring the voltage, current, and temperature of the battery pack. Using the data collected from these sensors, it estimates the battery's performance parameters. The voltage sensor, current sensor, and temperature sensor are responsible for sensing voltage, current, and temperature, respectively. The voltage sensor is connected in a shunt configuration, while the current sensor is installed in series with the load. The temperature sensor measures the temperature of the battery pack.

Various hardware components have been used, including sensors for measuring voltage, current, and temperature, the ESP8266 PROCESSOR Uno, a battery, and a BLYNK display. The BLYNK display presents information such as the state of charge (SoC), voltage, current, and temperature, as illustrated in Figure 1 of the block diagram. The sensors, which provide analog outputs for voltage, current, and temperature, are

connected to the analog pins on the ESP8266 PROCESSOR. The output port of the ESP8266 PROCESSOR connects to the BLYNK display, which displays the SoC, voltage, current, and temperature readings. Real-time data pertaining to the battery is shown on the BLYNK screen for enhanced reliability and protection.
The data is collected from the sensor and sent to the Controller, where various algorithms are executed. The Controller then transfers the data to the BLYNK display, which presents performance parameters such as State of Charge (SoC),Voltage, Current, and Temperature on the BLYNK interface. The microcontroller plays a important role in this process by measuring the current from the sensor. It integrates this measurement over time to determine the net charge that has either left or entered the battery. After performing some mathematical calculations, the microcontroller displays the results on the BLYNK interface.

❖ **Flow-Chart**

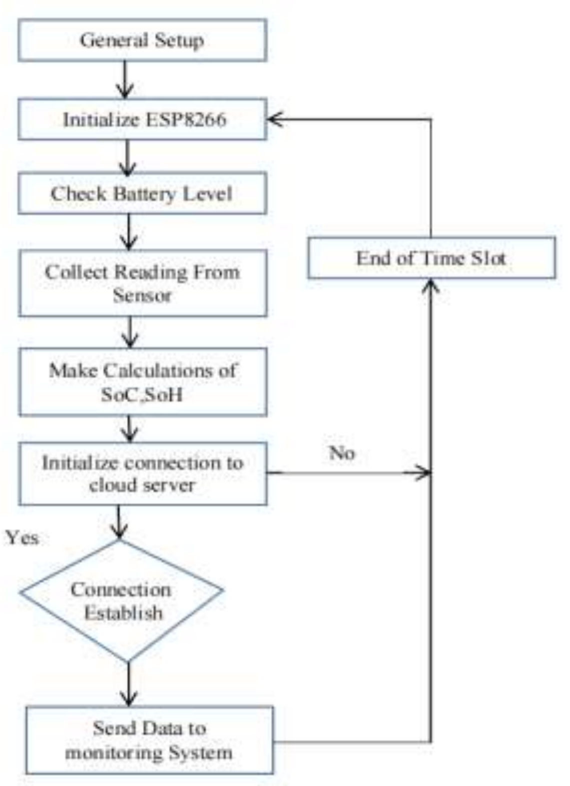

Fig 3 : Flow Chart

V. Components Used

The project necessitates particular hardware and software components for effectively monitoring and managing battery performance. On the hardware front, a microcontroller, such as the ESP8266, is essential for processing sensor data and assisting communications. Voltage and current sensors, like the INA219, will deliver accurate measurements of battery parameters, while a temperature sensor, such as the LM35, is essential for keeping track of battery temperature. The ESP8266 includes an integrated Wi-Fi module that allows for smooth cloud communication, although an external module can be used if necessary. Lastly, a dependable power supply unit is essential to power the entire system. On the software side, a microcontroller IDE, such as the Arduino IDE, is required for programming the microcontroller. Data storage and visualization will occur through a cloud platform like BLYNK. To create an engaging interface, data visualization tools will be employed to produce waveforms. Finally, a mobile or web application will grant users remote access to battery data, ensuring they can monitor performance at any time.
The project software requirements consist of a microcontroller integrated development environment (IDE), like the Arduino IDE, which will be used for programming the microcontroller. To support data storage and visualization, the Blynk cloud platform will be used, offering an easy-to-use interface for managing and presenting battery data. Besides, a mobile or web application will be created to enable users to access battery information from a distance, allowing them to monitor performance and receive real-time updates from any location. This combination of tools will establish an effective system for tracking and analyzing battery metrics efficiently.

VI. Working Mechanism

- Current and voltage sensor connected to battery charging point
- Battery Charging
- Energy Transmitted to load
- Current and voltage sensor connected to load side for discharging situation
- Both sensors are connected to ESP8266 module

VII. Implementation Of BMS Prototype

1. Current Sensing Current is detected using the ACS712 Fully Integrated, Hall Effect-Based Linear Current Sensor, which features 2.1 kV RMS Voltage Isolation along with a Low-Resistance Current Conductor. Five current sensors are arranged in series with the cell to measure the current. These sensors are connected to the analog pins of the ESP8266 PROCESSOR mega.
2. Voltage Sensing the voltage is measured using a voltage sensor module. Five voltage sensors are employed to capture the voltage. These voltage sensors are connected to the analog pins of the ESP8266PROCESSOR mega.
3. Battery Pack Temperature Sensing: The temperature of the battery pack is measured using the DHT11 temperature and humidity sensor. This sensor is connected to the A15 analog pin of the ESP8266 PROCESSOR mega.
4. SoC Estimation State of Charge (SoC) estimation using the coulomb counting method involves measuring the current flowing into and out of the battery over time in order to estimate how much charge has been added to or removed from the battery. This method is based on the principle that the total charge within a battery can be calculated by integrating the current over time.

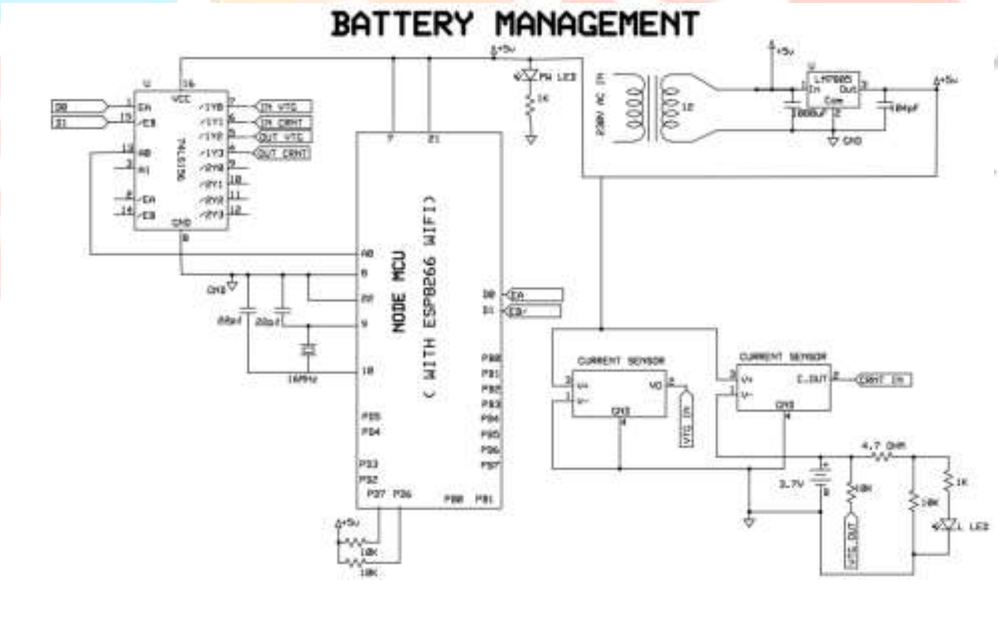

Fig.4. Battery Management Circuit

The fundamental equation for the coulomb counting method can be expressed as:

$$\Delta Q = \int (i(t)dt)$$

Where Q represents the total charge (in ampere-hours, Ah) that has either flowed into or out of the battery, i denotes the current (in amperes, A), and t is the duration (in hours, h) for which the current flows.
To estimate the SoC, the total charge (Q) is divided by the rated capacity (C) of the battery, and then multiplied by 100 to express it as a percentage. To determine you divide the total charge (Q) by the rated capacity (C) of the battery. Next, you multiply this result by 100 to convert it into a percentage value. The rated capacity (C)

refers to the maximum amount of charge that a battery can store, which is usually specified by the manufacturer.

$$SoC = \left(\frac{Q}{C}\right) * 100\%$$

Q= Charge Capacity of battery

VIII. Hardware Components Used

The CR-18650 Li-ion cell is a rechargeable battery that has a capacity of 1200mAh. It is recognized for its longevity, high energy density, and capability to endure up to 1000 charge-discharge cycles without a major loss in capacity. This battery is environmentally friendly and safe, making it suitable for continuous power applications when paired with a protection circuit board.

Fig.5. Rechargeable Li-ion Cell

This board protects against overcharging, over-discharging, and overcurrent. Another essential element in IoT applications is the ESP8266 processor module, which is an affordable SoC microchip that assists internet connectivity for embedded systems. The ESP8266 uses AT commands and allows for the loading of custom software, giving developers the ability to build specific IoT applications.

Fig.6. ESP8266 Module

For current sensing, the ACS712 module delivers accurate AC and DC current measurements through a Hall sensor. This sensor converts the magnetic field created by current flowing through a copper conductor into a corresponding voltage.

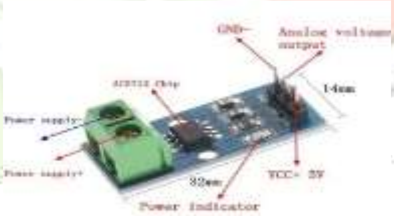

Fig.7. Current sensor

Voltage sensing is performed by a voltage sensor module which uses a resistive divider circuit to reduce input voltages of up to 25V. This makes it compatible with the 5V analog pin of the ESP8266 processor. The voltage divider comprises two resistors (30K and 7.5K) which diminish the output voltage by a factor of 5.

Fig.8. Voltage Sensor

The ESP8266's 10-bit ADC provides a resolution of 0.00489V, enabling the module to identify minimum voltage inputs as low as 0.02445V.In battery management systems (BMS), the IRF540 MOSFET is frequently employed to regulate the charging and discharging of lithium-ion batteries. This is due to its quick switching speed, high efficiency, and capacity to handle major current and voltage levels. The MOSFET's low on-resistance minimizes heat generation and enhances system efficiency. It operates with protection circuits that guard against overcharging, over-discharging, and short circuits, while also balancing battery voltage levels to prolong the battery's lifespan. Besides, 220-ohm resistors are used to dissipate excess charge and aid in activating the MOSFET during cell balancing.

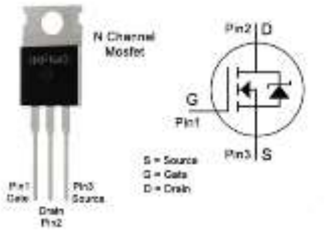

Fig.9. IRF540 MOSFET

Temperature monitoring is conducted using resistance temperature detectors (RTDs), which are generally made of platinum and have a resistance of 1000 ohms at 0°C. RTDs provide high accuracy across a broad temperature range (-200°C to 600°C) and are commonly used in industrial processes, laboratory instruments, and HVAC systems. They are usually configured with a three-wire connection to account for lead resistance, although they need periodic calibration to ensure accuracy. While RTDs are more expensive than thermocouples, they offer superior precision in temperature sensing.

Fig. 10. Temperature sensor

IX. Software Design Technique

Fig.11.BLYNK Display

Blynk's Internet of Things (IoT) model operates on a client-server architecture, where the mobile application is the client. This app communicates with the Blynk cloud server through the internet, using protocols like HTTP or WebSocket. This design assists smooth interaction between the mobile app and the connected devices. Besides, Blynk includes RESTful APIs, which allow the app to send requests to the cloud server for managing devices and retrieving sensor data, adhering to the principles of Representational State Transfer (REST).The platform is designed around an event-driven architecture. User actions, such as pressing buttons or adjusting sliders in the mobile app, trigger events that the cloud server processes. These events are then converted into actions performed on the hardware. To guarantee smooth operation, Blynk uses asynchronous programming techniques. This enables the mobile app to manage multiple tasks and device interactions at the same time without delays.Security is a major focus in Blynk's design. The platform employs secure authentication and authorization methods, including token-based authentication and SSL/TLS encryption, to protect user data and ensure safe communication between the client and server. The architecture is also modular and extensible, which allows developers to integrate custom features, device support, and plugins personalized to particular use cases.What's more, Blynk ensures cross-platform compatibility by supporting both iOS and Android devices. This provides users with a consistent experience regardless of the platform they are using. Overall, Blynk's software design prioritizes reliability, scalability, security, and flexibility, making it a strong platform for building and managing IoT applications and connected devices.

X. Advantages

The advantages of the proposed system can be summarized as follow:

[1] Improved Battery Performance and Life Optimized charging and discharging: A Battery Management System (BMS) ensures that batteries are charged and discharged within safe voltage and current limits, preventing issues such as overcharging and deep discharging, which eventually extends the battery's life. Balanced cell voltage: In systems with multiple cells, the BMS balances the voltage across individual cells to ensure equal contribution from all, thereby enhancing the overall performance of the battery pack.

[2] Enhanced Safety Protection against overheating: The BMS monitors the temperature of the battery to prevent thermal runaway, which can lead to overheating, fires, or explosions in certain battery chemistries. Prevention of short circuits and overloads: It protects against electrical faults such as overcurrent, short circuits, and overvoltage, ensuring safe operation of the battery system.

[3] Real-time Monitoring and Diagnostics Continuous data collection: A BMS continuously monitors parameters like voltage, current, temperature, and state of charge (SoC). This real-time data allows for early detection of any abnormalities or faults. Predictive maintenance: By continuously monitoring the system, the BMS can predict possible failures, reducing the chances of sudden battery issues and minimizing downtime.

[4] Increased Energy Efficiency Optimal power usage: By efficiently managing battery charging and discharging cycles, a BMS optimizes power usage, enhancing the energy efficiency of the entire system. Maximizing available capacity: The BMS ensures that the battery operates at its full potential without sacrificing safety, thereby improving overall energy availability.

[5] Cost Savings Extended battery lifespan: By proactively managing the health of the battery, a BMS helps reduce the frequency of replacements, leading to lower long-term costs. Reduced downtime: By preventing unexpected battery failures and assisting scheduled maintenance, a BMS helps avoid costly interruptions to the system.

[6] Remote Monitoring and Control Remote access: In many contemporary systems, the BMS can be integrated with communication modules for remote monitoring and control, particularly advantageous for large-scale or geographically distributed systems. Alerts and notifications: Automatic alerts and notifications can be sent to operators when the system identifies issues, ensuring quick responses to any problems.

XI. Applications

The proposed system can be employed at variety of applications such as :

1. Electric Vehicles (EVs)Battery management in EVs: The Battery Management System (BMS) is used to monitor and control the battery packs in electric vehicles, which helps in ensuring optimal performance, safety, and longevity of the battery. State of Charge (SoC) and State of Health (SoH) monitoring: This system tracks the SoC and SoH to provide accurate information regarding the remaining driving range and the condition of the battery.
2. Renewable Energy Systems Solar and wind energy storage: In systems that use renewable energy, such as solar and wind power, the BMS manages the energy stored in batteries, optimizing charge and discharge cycles while ensuring safe and efficient energy storage. Grid energy storage: Large battery systems for energy storage in smart grids use BMS to maintain a stable energy supply, manage peak loads, and connect renewable energy sources.
3. Telecommunications Uninterruptible Power Supply (UPS) systems: The BMS is employed in UPS systems for telecom towers to provide reliable power backup during outages or disruptions. Remote monitoring of telecom sites: BMS assists remote monitoring of battery status in off-grid or remote telecom towers, ensuring continuous operation and minimizing maintenance visits.
4. Data Centers Power backup systems: The BMS guarantees the reliable operation of backup batteries that support critical IT infrastructure in the event of power outages. Proper monitoring of battery health reduces the chances of downtime. Energy efficiency: By optimizing backup power system performance, BMS contributes to decreasing energy waste and enhancing overall energy efficiency in data centres.
5. Consumer Electronics Mobile devices: BMS is integrated into smartphones, laptops, tablets, and other portable electronic devices to optimize battery life, manage charging cycles, and prevent overheating. Wearable devices: In devices such as smart watches and fitness trackers, the BMS ensures efficient battery usage and guards against overcharging.

6. Electric Power Tools Battery-operated tools: For cordless power tools like drills and saws, the BMS manages battery life, ensuring proper function and preventing damage caused by over-discharge or overheating.
7. Railways and Public Transportation Electric trains and buses: The Battery Management System (BMS) is used in electric and hybrid trains and buses to oversee battery health, manage charge cycles, and ensure safe operation. Battery-powered signalling systems: The BMS guarantees the proper functioning of batteries that are essential for railway signalling and communication systems.
8. Industrial and Commercial Energy Storage Systems Energy management: The BMS is essential in energy storage systems (ESS) used in commercial and industrial environments, where it manages extensive battery banks for peak shaving, load balancing, and maintaining a stable energy supply. Off-grid energy storage: In remote areas or off-grid systems, a BMS is important for overseeing battery storage, particularly when paired with renewable energy sources such as solar or wind.
9. Robotics and Automation Battery-powered robots: In industries or warehouses, robots and autonomous systems depend on a BMS to keep their battery levels in check, ensuring uninterrupted operation. Drones and UAVs: For unmanned aerial vehicles, a BMS is essential for tracking battery usage and assuring flight safety by avoiding unexpected power loss.
10. Electric Bikes and Scooters Micro mobility solutions: Electric bikes, scooters, and various micro-mobility devices use BMS to monitor battery health, prolong battery life, and ensure user safety. Battery safety: The BMS protects against overcharging, over-discharging, and overheating in personal electric vehicles.

XII. Results

Figure.12. : BMS Model

Figure.13. : Blynk Display

Figure.14. : Graphical Representation

XIII. Conclusion

In conclusion, our IoT-based Battery Monitoring System project aims to optimize battery durability and efficiency while reducing energy waste. By designing an effective, scalable solution that integrates real-time monitoring, predictive maintenance, and smart charging, we are committed to ensuring the reliability and longevity of batteries across diverse applications. This initiative's incorporation of IoT technologies not only promises cost efficiency but also provides environmental advantages, establishing it as a vital asset for industries, households, and electric vehicles within a continually evolving IoT and energy monitoring framework. Overall, the BMS offers a holistic solution that enhances battery operation, prolongs its lifespan, and safeguards user safety. This project exemplifies the effective integration of numerous components and algorithms to develop an efficient and reliable Battery Monitoring System for lithium-ion batteries.

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