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Optimization Techniques for Battery Health Monitoring and Management

Grishma Nitin Sathe[1], Pramod Devakate[2], Shailesh Bhure[3]*, Shashikala. A. Koti[4]

[1,2,3]Students, Department of Electrical Engineering, Sinhgad College of Engineering, Sinhgad Campus,Vadgaon-Budruk,Pune-411046, Maharashtra, India

[4]Professor, Department of Electrical Engineering, Sinhgad College of Engineering, Sinhgad Campus,Vadgaon-Budruk,Pune-411046, Maharashtra, India

Author for Correspondence Email- shaileshbhure.scoe.entc@gmail.com

Abstract

The "IoT-Based Battery Management System" project represents an innovative solution to address the growing demand for efficient and intelligent battery monitoring and management across various applications. In order to achieve maximum efficiency from a multi-cell Li-ion battery, every cell inside the battery must be "matched." Most battery safety and qualification standards demand that a battery be built entirely of compatible cells. Still, not much work is done to ensure that all of the cells remain matched over the battery's lifespan.Regular use and calendar aging (the battery is only stored) both contribute to the mismatching of the battery's cells. A continuous or intermittent external short of even a single cell in a multi-cell battery can also result in cell mismatch. Internal shorts, uneven cell *heating, and defective chargers are other issues that might cause one or more cells to overcharge. With the proliferation of battery-dependent technologies in fields like renewable energy, electric vehicles, and industrial systems, ensuring the safety, longevity, and reliability of batteries has become paramount.*

Keywords: Battery Management, monitoring System, ESP8266, Lithium-ion battery, BMS.

INTRODUCTION

For optimal battery performance in a multi-cell Li-ion battery, each cell in the battery needs to be "matched." The majority of battery safety and qualification requirements mandate that a battery be constructed exclusively from compatible cells. However, not much effort is put into making sure that every cell stays matched during the course of the battery's life.

The battery's cells tend to become mismatched as a result of both regular operations and calendar ageing (the battery is just stored). Cell mismatch can also brought on by a persistent or sporadic external short of even a single cell in a multi-cell battery. Additional problems that could lead to one or more cells overcharging include internal shorts, uneven heating of the cells, and malfunctioning chargers[9],[10]. Throughout the battery lifecycle, a battery management system (BMS) should be able to detect mismatched cells in order to guarantee safety. Cell matching is actually only done during the battery manufacturing process—it is not done later.In the use of the electricity system, batteries play a crucial role as energy storage in electric vehicles, renewable energy power plants, and portable electronic devices.

as in a microgrid system that is smart. A battery with good performance would give the associated system the best possible assistance for its functioning. The ESP8266, known for its Wi-Fi capabilities and low-cost profile, has found its way into numerous IoT applications. When applied in a BMS context, the ESP8266 facilitates real-time monitoring and control, enabling remote access to critical battery information.

Longer battery usable life can be achieved if the battery is

either when the battery is being charged or discharged, kept in the safety operating area (SOA). Inappropriate pricing and

Processes for draining batteries may result in reduced performance and a shorter useful life.

To address the dynamics of the battery's energy storage process and increase battery life, a battery management system, or BMS, is required. The two operational facets of BMS are control and monitoring.

The control aspect and the monitoring aspect are inextricably linked.

A quick, accurate, and precise monitoring system is needed to conduct proper control of battery charging and discharging processes [1]. An ideal BMS will use less power and be energy-efficient, allowing the battery to reach its maximum capacity.

The BMS makes sure that excessive charging, excessive discharging, or excessive power consumption during a load won't harm the battery [2]. When charging and discharging a battery, the BMS will check its operating characteristics, such as voltage, current, and internal temperature, and it will estimate the battery's state, including its state of charge (SOC) and state of health (SOH).

Recently, research and development in the fields of electric car and alternative energy systems have focused on developing a BMS that is versatile enough to safeguard various battery types and can offer all the safety features [3]. According to [2], a full-featured BMS should have the following capabilities: data collection, safety protection, the capacity to ascertain and forecast battery condition, control over charging and discharging, cell balancing, thermal management, delivery of battery status and authentication to a user interface, communication with all BMS components, and, above all, extending battery life. In order to relate the input current rate and its state of charge (SOC) estimation, a battery model is required; coulomb counting techniques can be quite useful for this. Equation (1) [4] [5] represents one of the SOC estimate algorithms that is based on coulomb counting and accounts for the coulomb efficiency for monitoring systems in discrete time.

$$SOC_k = SOC_{k-1} + \frac{\eta_i i_{k-1} \Delta t}{C_n} \tag{1}$$

where ηi is the battery's coulombic efficiency while charging and discharging and k is a time variable. The ratio of electrons spent during charging or discharging processes to their corresponding available electrons is described by this factor. It is hypothesized that this ratio will be 1.0 during the discharging phase and 0.992 during the charging period [5]. This integration allows users to keep a close eye on battery health, performance, and environmental conditions. The necessity for a sophisticated Battery Management System (BMS) has increased along with the demand for dependable and efficient energy storage options. The goals of our IoT-Based Battery Management System project are to increase battery longevity in a variety of applications, optimize battery performance, and guarantee safety.
The microprocessor receives data from the battery sensors, which detect the battery's voltage, current, and temperature. The necessity for a sophisticated Battery Management System (BMS) has increased along with the demand for dependable and efficient energy storage options. The goals of our IoT-Based Battery Management System project are to increase battery longevity in a variety of applications, optimize battery performance, and guarantee safety. The objective of this system is to facilitate the smooth management of batteries in various industries and sectors by utilizing IoT technology to offer real-time monitoring, data-driven insights, and remote accessibility.

1.1 EXISTING SYSTEM

The existing battery management system (BMS) typically monitors and controls key parameters of a battery pack, such as voltage, current, temperature, and state of chargeIt does this by controlling temperature, avoiding overcharging or overdischarging, and balancing individual cells to guarantee maximum performance, safety, and longevity.

Certain aspects, such as renewable energy storage or electric vehicles, differ according to the application. advancements in BMS aim to enhance efficiency, reliability, and integration with emerging technologies

1.2 PROPOSED SYSTEM

Certain aspects, such as renewable energy storage or electric vehicles, differ according to the application. advancements in BMS aim to enhance efficiency, reliability, and integration with emerging technologies Some potential areas for improvement or features that could be considered in a proposed BMS Explore more advanced cell balancing techniques to ensure that individual cells within a battery pack are consistently charged and discharged. This can enhance overall battery pack performance and lifespan. Apply predictive maintenance algorithms to foresee possible problems by utilizing real-time monitoring and previous data. By doing so, maintenance schedules can be optimized and unplanned breakdowns can be avoided. Create better thermal management methods to efficiently control battery pack temperature.. This can prevent overheating and enhance overall safety and performance. Improve communication protocols for seamless integration with other vehicle or energy management systems. This includes better compatibility with emerging technologies like Vehicle-to-Grid (V2G) or smart grid applications

2. DESIGN AND DEVELOPMENT

2.1 OBJECTIVES

1. Fault Detection and Alerts: Integrate sensors and algorithms to detect potential faults or anomalies in the battery system, and send immediate alerts via the 4G GSM module to prevent critical issues.
2. Remote Monitoring: Enable real-time monitoring of battery status, including voltage, current, temperature, and overall health, through IoT connectivity.
3. Data Logging: Implement a robust data logging system to record historical battery performance data, aiding in trend analysis and predictive maintenance.
4. Power Optimization in Communication: Implement strategies to optimize power consumption during communication through the 4G GSM module, ensuring minimal impact on the overall battery life.

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2.2 TOOLS AND TECHNOLOGIES

Hardware Components

1. **NODEMCU:** A development board called the Node MCU is built around the ESP8266 Wi-Fi module. It offers internet connectivity[6].
2. **INA219aid:** The INA219AID is a high-side current and voltage monitor with I2C interface.
3. **OLED-DISPLAY:** The OLED display is used for visualizing data, such as battery voltage, current, or other relevant information[7].
4. **DHT11:** The DHT11 is a basic temperature and humidity sensor.
5. **GPS NEO 6M MODULE:** The GPS module allows you to track the location of your battery powered device[8].
6. **GSM 800L MODULE:** It can be used for sending SMS notifications or remotely controlling the system.
7. **BUZZER:** The buzzer can be used for generating alarms based on certain conditions.
8. **BATTERY(LIPO):** To guarantee secure and effective functioning, it is imperative to keep an eye on its voltage, current, and temperature.
9. **DC MOTOR WITH SINGLE CHANNEL RELAY:** The DC motor is used for controlling external components or devices[9]
10. **PUSH BUTTON:** The push button can be used for manual inputSoftware Components

1. **Arduino IDE** - As an IDE for Arduino Mega code.
2. **C** - Programming language.
3. **Proteus** -. For designing and simulating electronic circuits.

METHODOLOGY

Deep drain and excessive charging shorten the rechargeable battery's lifespan. Because the car is electrically powered, there is a greater risk of short-circuiting, which can cause a fire in rare circumstances, such as when the temperature suddenly rises. Under any conditions, EV users risk falling into the rubbish if they are unaware of the obstruction in front of or adjacent to their car. Due to battery safety concerns, EVs have several constraints. An exorbitant fee for clarification could cause an explosion or gas leak. In an electric vehicle, a battery powers everything. The electric vehicle's battery is its fundamental component. To ensure security, durability, maximum efficiency, and financial feasibility, a correctly built real-time BMS is essential for battery condition evaluation. Charge standardization increases the machine's lifespan and protects it. The use of recyclable batteries decreases reliance on other types of energy, lowering greenhouse gas emissions. Because lithium is a highly reactive chemical, the BMS must guarantee that each lithium battery remains within predetermined limitations. In the long run, this will protect and preserve the battery. When the BMS cell is down or exceeds specified criteria, it may be detected and maintained. Because lithium is a highly reactive chemical, the BMS must guarantee that each lithium battery remains within predetermined limitations. In the long run, this will protect and preserve the battery.

Flowchart: Flow Chart of information by proposed system is shown in Figure 1.

FLOWCHART

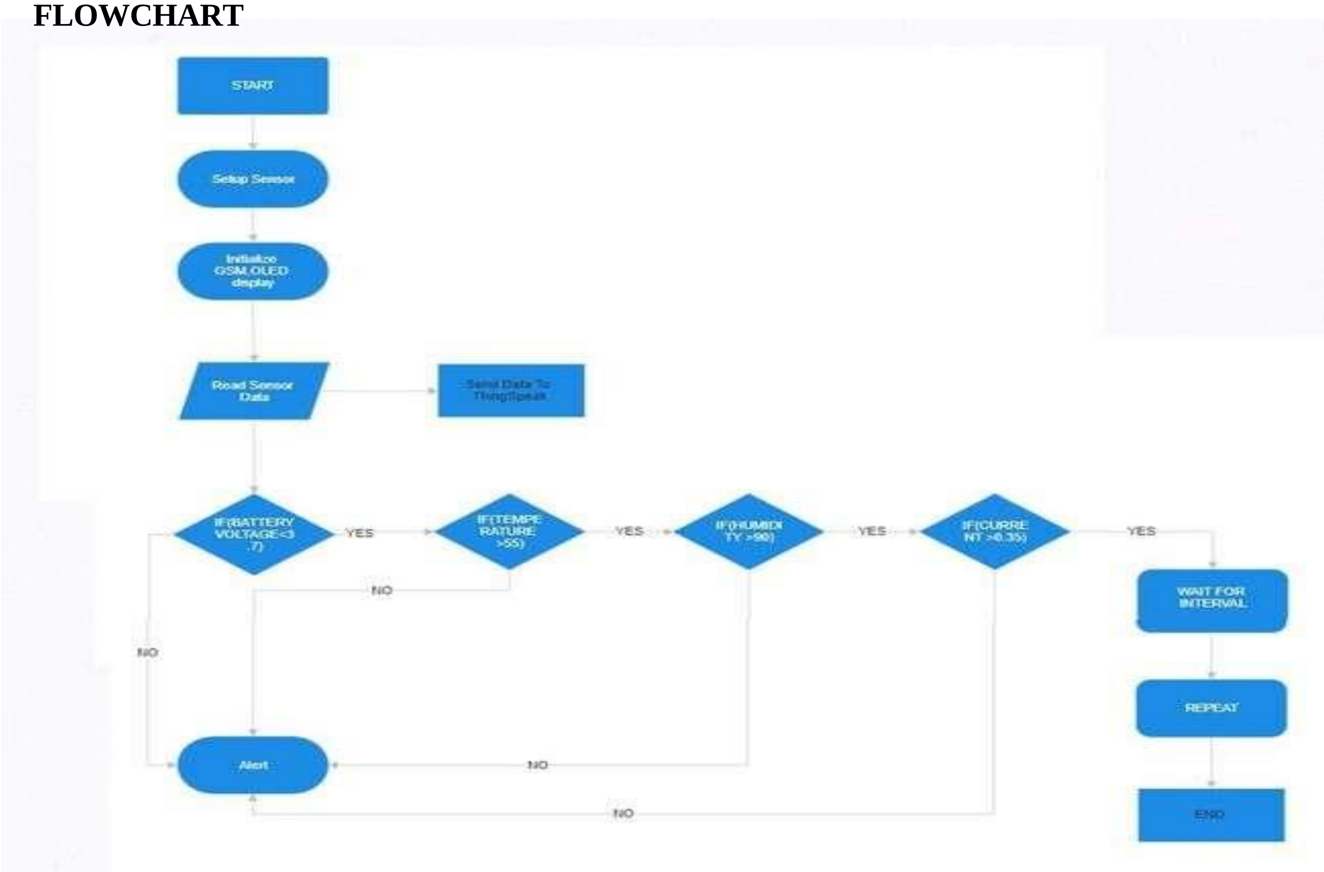

Figure 1. FlowChart of information by proposed system

2.2 Results

Below are the Figures that describes Battery Management System Implementation and Results. Figure2 shows the implementation of Battery Management System and the connection of components.Figure 3 shows the expected result of ThingSpeak which shows current , voltage and tempreatures graphical representation.

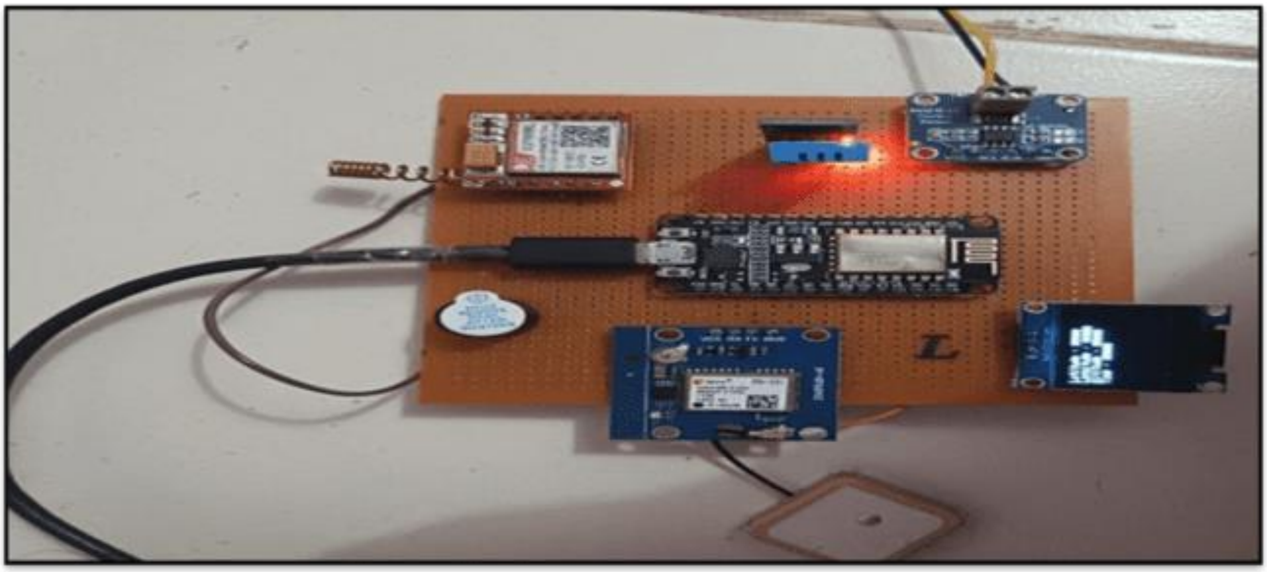

Figure 2. Picture of Developed Model

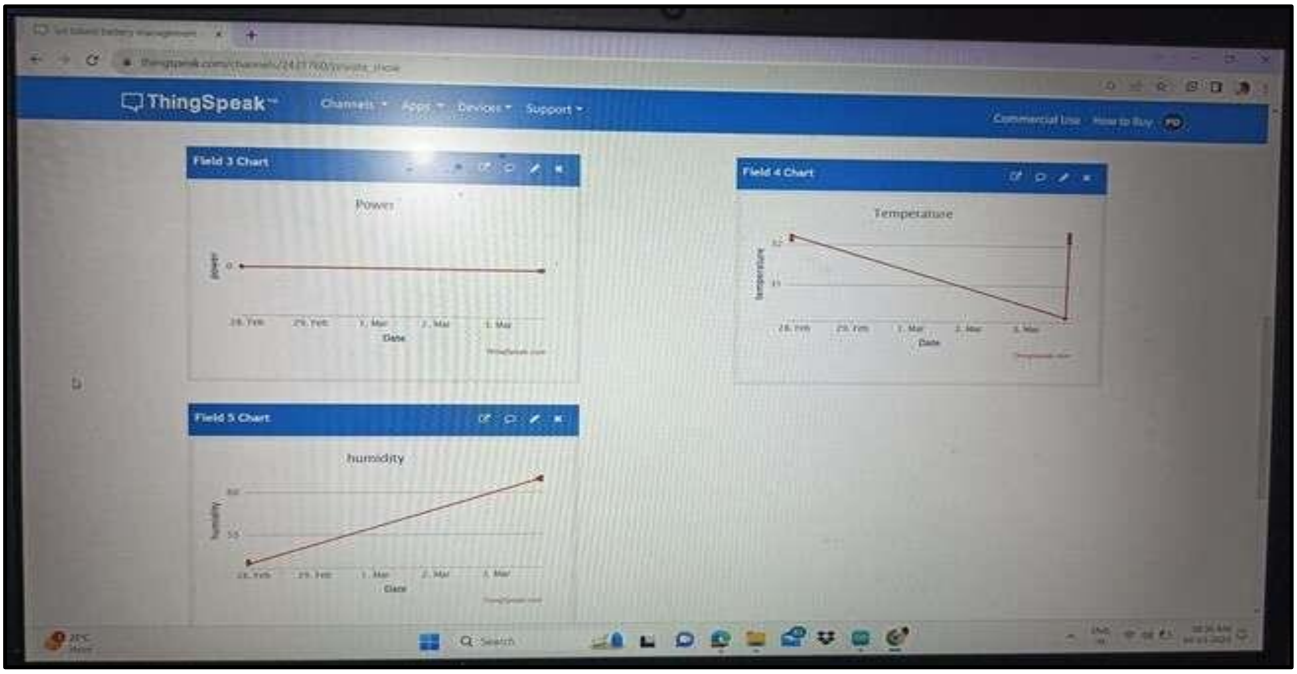

Figure 3. ThingSpeak Application Output

Result: IoT-Based BMS for 3.7V LiPo Battery

The results of the IoT-based Battery Management System (BMS) for monitoring a 3.7V LiPo battery. The system collects and analyzes data from various sensors, including the INA219B for voltage and current monitoring and the DHT11 for temperature and humidity measurements. The system operates within normal parameters until certain abnormal conditions trigger alerts. This real-time monitoring and alerting capability help ensure the safety and reliability of the battery make informed decisions about the battery's performance and maintenance needs. The state of charge (SoC) and state of health (SoH) parameters are vital for assessing the battery's overall condition and predicting its remaining lifespan.

Table 1. Temperature, voltage, current and health of battery with battery status

Table 1. Result

Time	Battery Voltage (V)	Battery Current (A)	Temperature (°C)	Humidity (%)	State of Charge (%)	State of Health (%)	Alerts/Status
9:00 AM	3.78	0.2	25	50	95	100	Normal Operation
9:05 AM	3.77	0.25	25.5	51	94	99	Normal Operation
9:10 AM	3.76	0.3	26	52	92	98	Normal Operation
9:15 AM	3.75	0.35	26.5	53	90	97	Abnormal Current
9:20 AM	3.74	0.4	27	54	88	96	Abnormal Current
9:25 AM	3.73	0.45	27.5	55	85	95	Abnormal Voltage
9:30 AM	3.72	0.5	28	56	82	94	Abnormal Voltage, Over-temperature
9:35 AM	3.71	0.55	28.5	57	79	93	Abnormal Voltage, Over-temperature
9:40 AM	3.7	0.6	29	58	76	92	Abnormal Voltage

Above table 1. shows temperature, voltage, current and health of battery with battery status.

3. CONCLUSION

IoT-based Battery Management System BMS integrates multiple sensors, including the INA219 for voltage and current monitoring and the DHT11 for environmental data, providing real- time insights (BMS) that addresses the critical need for efficient battery monitoring, management, and optimization in various applications. Then examines the battery health and performance.

The key features of our IoT-based BMS include wireless monitoring, remote accessibility, data analytics, and a user-friendly OLED display. It allows for continuous tracking of voltage, current, temperature, and humidity, enabling comprehensive assessment of battery parameters. The BMS not only provides valuable information for battery health and performance but also contributes to safety and cost-efficiency by detecting critical events such as fuel theft. To further measure the battery's remaining capacity and general condition, we have incorporated state-of-charge (SoC) and state-of-health (SoH) computations. These metrics are crucial for predictive maintenance, ensuring the longevity of batteries and reducing the cost of ownership. The IoT capabilities of our BMS enable remote access and data storage in the cloud, promoting ease of use and accessibility for users.

The system can be applied in various fields, including renewable energy systems, electric vehicles, and industrial machinery, to ensure efficient energy storage and distribution. In conclusion, our IoT-based Battery Management System provides a comprehensive solution for battery monitoring, management, and optimization. It empowers users with valuable insights, enhances safety, and promotes cost savings, contributing to sustainable and efficient battery usage in wide range of application.

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