China Petroleum Processing and Petrochemical Technology

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 4845-4853

SMART BMS HARDWARE IMPLEMENTATION FOR RENEWABLE E-VEHICLES

J.S.LindaJohnsana
Research Scholar,EEE, Saveetha Engineering college, Chennai, India

Dr.P.Selvaraj
Associate Professor, Electrical and Electronics Engineering, Dr.M.G.R.Educational and Research Institute

Dr.R.Kalaivani
Professor, Electrical and Electronics Engineering, Rajalakshmi Engineering College

Dr. T Kaliraja
Professor, ECE, SV college of engineering, Karakambadi road, Tirupati

Dr.R.SenthilKumar
Professor, EEE, Saveetha Engineering college, Chennai, India

Abstract— The transition towards a sustainable and decarbonized transportation sector has led to a significant increase in the adoption of electric vehicles (EVs). EVs have many benefits, such as lowered emissions and improved energy efficiency. However, the performance and longevity of the EV's battery pack heavily rely on an efficient Battery Management System (BMS). This paper explores the hardware implementation of a BMS specifically designed for renewable energy electric vehicles. The study highlights the importance of BMS in optimizing the performance, safety, and longevity of EV batteries and discusses various hardware components and techniques involved in its implementation. Furthermore, the paper presents key challenges and potential solutions associated with BMS implementation for renewable energy EVs, along with future research directions.

Keywords— Battery Management System; Batteries; Hardware implementation; RES, Smart EV.

I. INTRODUCTION

Battery management systems (BMS) serve a vital role in maintaining the effective use of batteries in automobiles by monitoring and regulating charging and discharge activities. BMS systems protect batteries from overloading, severe drain, and overvoltage. The BMS calculates the battery's state of charge (SOC), state of health (SOH), and the required current for safe charge and discharge operations. This lengthens the battery's life and protects it. Overall, BMS systems help to optimize battery use and the safe and efficient operation of autos. The battery management system also has a cell balancing feature for multi-cell batteries to make sure that each battery cell's charging and discharging needs are satisfied. The battery management system monitors each cell in the battery pack. Calculating the SOC and SOH of a battery aid in calculating the amount of current required

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 4845-4853

for a safe charge and discharge operation without causing harm to the battery. The current limits act as a cut-off, preventing the battery from becoming overcharged. This safeguards the cell voltages of the battery pack from high and low changes, hence extending battery life. The BMS continuously tracks cell voltages and the battery pack's charge and discharge events. This data is useful in detecting whether or not the battery is fully charged, allowing passive cell balancing to continue. Designing a battery management system that uses two energy sources—renewable solar energy and an electric source—is the main goal of this effort. Measuring the State of Health (SoH) and State of Charge (SoC) of the battery pack to learn about the health of the battery. To provide IoT-based information about e-vehicle battery levels at any time, and to allow the user to examine and analyze the information history.

Based on prior research papers [1] The paper emphasizes the importance of the battery in electric vehicles and highlights the need for ongoing research and development in the field. It acknowledges the dominance of lithium-based chemistry while acknowledging the potential for further advancements. The role of a BMS in monitoring and controlling battery operations is emphasized, highlighting its significance in achieving optimal battery performance [2] The need for alternative and eco-friendly transportation has led to the rise of electric and hybrid-electric vehicles. Lithium chemistry-based cells are commonly used as the power source for these vehicles. These types of cells are toxic and explosive in adverse situations, so battery packs constructed from them need to be constantly monitored.

Because of its high energy density and power rating, Li-ion chemistry is currently the technology of choice. Choosing the right battery chemistry is essential for overall system performance. A Battery Management System (BMS) is necessary for Li-ion batteries in order to keep each cell within the acceptable working range and prevent overcharging, over discharging, and use outside of the safe temperature range.[3] The objective is to provide an open-sourced BMS for monitoring big battery packs without sacrificing user or system safety. Many automakers have proprietary BMS designs. Li-ion chemistry requires battery monitoring to guarantee extended battery life and energy efficiency. Voltage, current, temperature variation, and State-of-Charge (SOC) are the four primary battery monitoring parameters. Temperature changes in cells can indicate cell failure, making it an important parameter to consider. The development of an open-sourced BMS aims to benefit the entire community and enhance the safety and performance of large battery-packs.

II. BATTERY MANAGEMENT SYSTEM (BMS)

The evolution of battery management systems (BMS) has been a slow and steady process that has lasted several decades. The earliest BMS were created in the 1970s and 1980s for use in aerospace and military applications where battery reliability was crucial. These early systems were primitive and relied on simple voltage and temperature sensors to check the health of the battery. With the rise of electric cars (EVs) in the 1990s, BMS got more complex and sophisticated. Companies such as GM and Toyota were among the first to create commercial BMS for EVs, which used micro controller to monitor battery voltage, temperature, and current. The introduction of lithium-ion batteries in the early 2000s led to significant advancements in BMS technology. These technologies could provide more precise and detailed data on battery health, such as SoC and SoH

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 4845-4853

information. BMS are now employed in a variety of applications, such as EVs, renewable energy systems, and consumer electronics. They have advanced, utilizing advanced algorithms and machine learning approaches to optimize battery efficiency and lifespan. To enhance battery performance, safety, and dependability, technology development has researched the expansion of BMSs.

In an existing system, a hybrid approach of cascaded multilevel converter on three-level cells can be used to generate additional voltage levels in each cell while also retaining energy in the battery cells. It can be obtained by combining the effective clamping approach of Three-Level strategies with the inverting H-bridge method. In this scenario, the H-bridge's series connection is used to cascade together the three levels, each of which has a separate dc source. The output ac voltage at each level can be calculated with few series units and may be almost perfect sinusoidal. With the help of an inverter, the output voltage can be sent to the motor vehicle. [4]

The system presented here is made up of temperature and voltage sensors, an Arduino Uno microprocessor, and an LCD display. The development of system given by three main goals. To begin, a mathematical equation was developed to establish the link between the input and output of the sensors. This equation was verified by observing the sensor outputs with and without loads. Next, BMS prototype was made by connecting the sensors to sense current and voltage and the LCD to the Arduino Uno controller. When no load was attached, the current sensor registered zero, and the webpage and LCD displayed 11.1V when the battery was fully charged, according to the prototype's testing using an 11.1 V Lithium-ion battery. The designed system allows users to monitor the battery's current, voltage, and SoC to avoid overcharging and overuse. The BMS prototype has the potential to benefit consumers by monitoring battery performance in any electronic system. Overall, the whole BMS prototype makes work easier and improves the user experience.

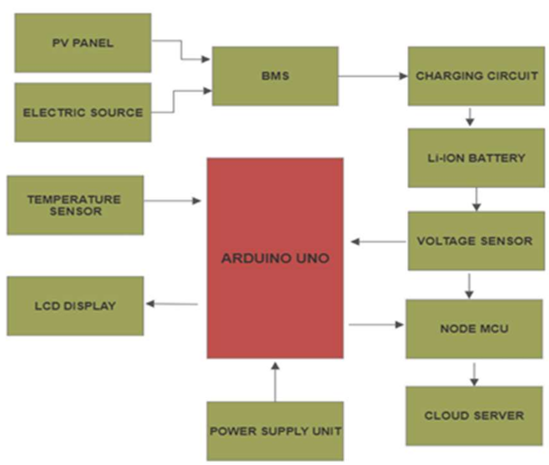

Fig. 1. Smart BMS Block diagram

III. HARDWARE COMPONENTS OF BMS FOR RENEWABLE ENERGY EVS

This hardware is designed to continuously monitor the vital parameters of individual battery cells such as Voltage, Current, and Temperature control and measurement, SOC and SOH assessment. The data can be viewed online and is kept in a database on a cloud server. The major goals of this system are to monitor battery levels, update data online, and notify users of any faults. The Monitoring Unit transmits real-time data to the Cloud Server where the Arduino is connected via the Node MCU module in order to track the battery level. To facilitate understanding, the complete system's construction can be separated into the following modules:

1. Sensor Interfacing
2. Setting Up the Power Supply Unit
3. Programming Microcontrollers
4. Analogue Data Reading
5. Testing and Debugging

A. SENSOR INTERFACING

Analog-to-digital conversion, signal conditioning such as amplification and filtering, and other signal processing are all a part of sensor Unit. Your microcontroller may have an analog-to-digital converter (ADC), but the sensor needs to work with the ADC input.

B. PREPARING POWER SUPPLY UNIT

The internal components of a controller get low-voltage, regulated DC power from a power supply unit, which converts mains AC. 240 volts AC is transformed into a more usable voltage, such as 12 volts DC, using a power supply. Linear and switch mode power supplies are the two categories under which they fall. To lower the voltage in a linear power supply, a transformer is utilized. High DC voltage is generated by converting and controlling the AC signal.

An AC plug is placed in case which resembles AC adapter, AC/DC adapter, or AC/DC converter. Chargers or rechargers are other names for adapters used with battery-operated devices.

Electrical equipment which needs electricity which is not sufficient from internal components are connected to AC adapters. An external power supply's internal circuitry is remarkably similar to the architecture of an internal or built-in supply.

C. MICRO-CONTROLLER PROGRAMMING

A microcontroller is an integrated circuit that may be programmed to carry out a number of different tasks. Microcontrollers come in a number of forms and offer a wide range of functionality. One of the most potent tools in contemporary design, the microcontroller excels in versatility.

D. READING ANALOG DATA

The analog-to-digital converter in the board's microcontroller reads this fluctuating voltage and transforms it to a value between 0 and 1023. The input value is 0 and there are 0 volts coming to the pin when the shaft is fully rotated in one direction. Analogue Reading returns to a value between 0 and 1023 that is inversely proportional to the voltage supplied to the pin in between.

E. TEST AND DEBUG

Testing is possible at every level of module development, including requirement analysis, interface design, algorithm design, implementation, and module integration. Implementation testing comes in other forms besides execution testing. Additionally, as will be covered below, peer reviews, code tracing, and correctness proofs can be utilized to test an implementation.

Execution testing and code improvement are both steps in the cyclical process of debugging. Testing for debugging has a different goal than testing for the finished module. Debugging testing looks for errors, whereas final module testing aims to show accuracy. This divergence significantly affects the choice of testing methodologies.

IV. BMS IMPLEMENTATION

F. ARDUINO UNO:

Arduino is an open-source electronics platform that utilizes simple hardware and software. It allows users to control various components such as motors and LEDs, and enables the publication of projects online.

The Arduino Uno, a popular microcontroller board, is based on the ATmega328 microcontroller and includes a 16 MHz crystal oscillator, 6 analog inputs, 14 digital input/output pins, a USB port, a power jack, an ICSP header, and a reset button.

The board can be programmed using the Arduino IDE, which is based on the Processing programming language and supports C and C++. It provides serial communication ports, including USB, for loading software from personal computers.

Overall, Arduino offers a user-friendly platform for creating interactive projects and sharing them with the online community.

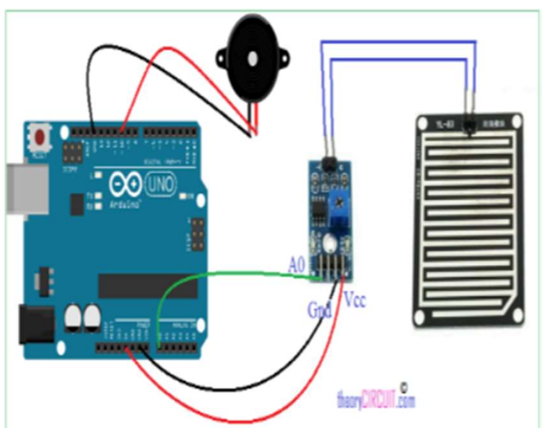

Fig. 2. Arduino interface with sensor & buzzer

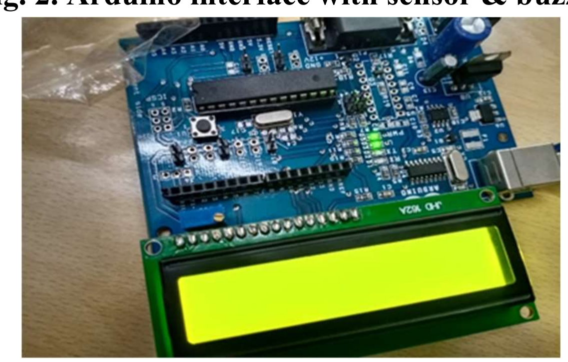

Fig. 3. LCD interface with Arduino

G. SYSTEM IMPLEMETATION

Arduino Uno board is first interfaced with the LCD display and the LM35 temperature sensor. The output from the voltage sensor and temperature sensor connected to the batteries are given as the input to the Arduino Uno and this data is sent to the LCD for data display and to the Node MCU as well for exchanging data between devices using Wi-Fi connection.

Charging ports for Solar charging as well AC input charging are present in designed hardware. In a scenario where both charging ports are used to charge the designed system, this can lead to hardware damage of the Solar panel. In order to avoid that, Reverse bias circuit is introduced using diodes within the system (only single direction of current passing is allowed within the system).

The temperature sensor, voltage sensor, and lithium-ion batteries are all interconnected. And there is BMS circuit placed within the system. There are two charging ports available for both power sources as per the User's necessity and choice (Solar power charging port and AC input charging port).

V. RESULTS

The suggested BMS circuit has been simulated and is displayed.

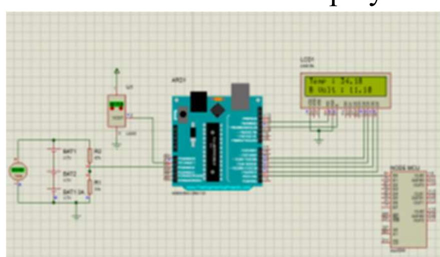

Fig. 4. PROTEUS Simulation Output

H. HARDWARE SYSTEM SETUP

The Solar panel can be connected to the hardware setup for charging the whole circuit when the User is unable to find an electric charging power source in remote location or to conserve energy and the environment.

Similar to this, when the weather is erratic, or when solar power cannot be relied upon as a power source, the user can use the AC input charging connector with a power supply adapter.

For the purpose of monitoring the Li-ion batteries, the following battery health parameters of the patient are measured and displayed on the LCD display:

- **Battery Voltage**
- **Temperature**

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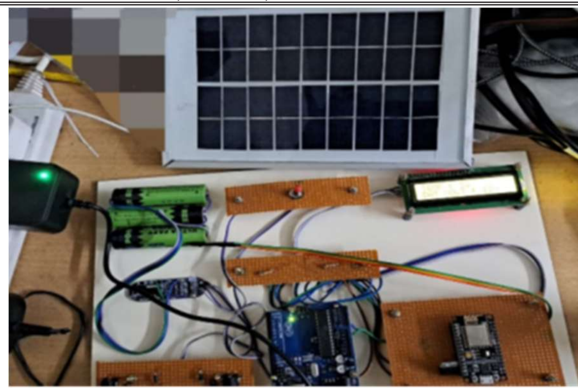

Fig. 5. Image of the whole hardware system setup

I. SOFTWARE SETUP

A webpage has been designed to display the collected data for battery monitoring. The option to view detailed history is also given on the webpage which would be most useful for vehicle drivers to have a control on the battery health and maintain vehicle safety.

Fig. 6. Image of the working hardware system setup

IOT BASED ENVIRONMENTAL MONITORING SYSTEM

S.no	Temperature	Battery Level	Date And Time
1	31	12	2023-03-14 17:42:29
2	31	12	2023-03-14 17:42:28
3	31	12	2023-03-14 17:42:26
4	31	12	2023-03-14 17:42:24
5	31	12	2023-03-14 17:42:23
6	31	12	2023-03-14 17:42:21
7	31	12	2023-03-14 17:42:19
8	32	12	2023-03-14 17:42:18
9	31	12	2023-03-14 17:42:16
10	31	12	2023-03-14 17:42:14
11	31	12	2023-03-14 17:42:13
12	32	12	2023-03-14 17:42:11
13	31	12	2023-03-14 17:42:09
14	31	12	2023-03-14 17:42:08

Fig. 7. Image of the webpage setup

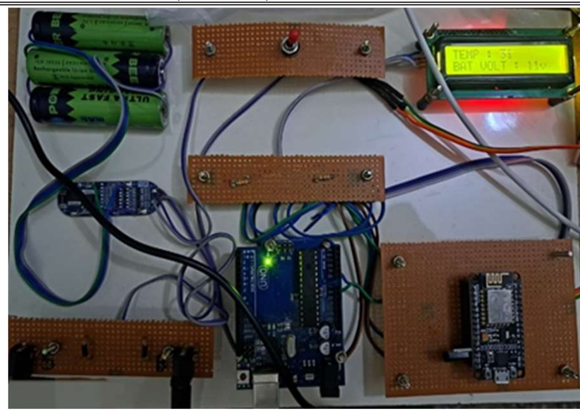

Fig. 8. Image of the detailed battery health history

Thus, the detailed history of the battery health parameters is recorded on the webpage for anytime reference and data monitoring by the user by using their phone or desktop devices using internet.

VI. CONCLUSION

A BMS extends the life of battery cells. This is an efficient mechanism for living and controlling the voltage of the cell. It offers stability and dependability. It protects the battery pack, particularly big format lithium-ion batteries. It regulates the temperature. It constantly monitors the battery cells to prevent failure or explosion. The quantity of charge in the battery fluctuates greatly depending on the temperature. To create a better BMS, we must first understand the relationship between temperature and SOC. Also, the precession must improve over time, thus we should aim to combine more hybrid approaches to prevent difficulties like early discharge. The trend of electric cars is catching up, and the market is looking for better solutions for EVs, and this technology can be best accommodated in E-Rickshaws due to their heavy use of the Lead Acid battery. It might be conceivable to combine the controller for motor drive with the BMS. Better efficiency and power can be achieved with the help of a better understanding of the batteries under various conditions and a smarter battery management system.

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