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Review of Battery Management Systems (BMS)

Nikita Shelke[1], Chaitali Nilawar[2], Gajajnan Udas[3]

[1] *Design Engineer, Tata technologies Pune.*
[2] *Deputy General Manager, Tata Motors Pune.*
[3] *Sr. Team Lead – Engineering, Tata technologies Pune.*

Abstract - *The most crucial component of any electric vehicle (EV) is its battery storage, which stores the energy needed for the vehicle to function. So, an effective battery management system is required in order to get the most out of a battery while also ensuring its safe operation. BMS is a crucial component of any electric car, so there is still a lot of research going on to improve battery management systems.*

Monitoring, regulating, and optimizing the performance of the battery modules in an electric vehicle is very important. Another is the ability to regulate how the components are disconnected from the system in case of irregular conditions. This management system is nothing but the "battery management system (BMS)". BMS keeps track of the parameters, calculates SOC, and offers essential services to assure the battery's safe functioning. The functionality of BMS, topologies of BMS, and future technologies like wireless BMS are all thoroughly reviewed in this paper.

Key Words: EV (Electric Vehicle), BMS (Battery Management System), SOC (State of Charge), SOH (State of Health), WBMS (Wireless BMS)

1. INTRODUCTION

Research indicates that automobiles with internal combustion engines are responsible for producing 18% of the suspended particles, 27% of the volatile organic substances, 28% of Pb, 32% of nitrogen oxides, and 62% of the CO of airborne pollution in America [7]. Moreover, traditional cars are responsible for 25% of all atmospheric CO2 that is related to energy and is the main contributor to the greenhouse effect [7]. The number of people using both public and private transportation is growing, which contributes to daily increases in air pollution. As a result, electric cars are getting more popular.

The following essential parts are often found in an electric car: an electric motor, MCU, traction battery, BMS, plug-in charger that can be used independently from the vehicle, wiring harness, regenerative braking system, vehicle body and frame. When utilizing lithium-ion batteries, the battery management system is one of the most important parts.

The system battery pack's operational safety is verified by the BMS model. A BMS's main purpose is to protect the battery. Monitoring each cell is essential due to ageing problems, cell balancing concerns, and safety concerns. Moreover, BMS makes sure that any abnormal state in the system is addressed by the predetermined corrective procedures. The BMS controls the system temperature because a rise in temperature may affect the power consumption profile of the system [1].

The BMS should notify the user and carry out a corrective operation whenever any abnormal circumstances, such as overvoltage or overheating, are detected [5]. The BMS took actions based on the factors such as battery charging and discharging rates, cell voltage, temperature, current, estimated state of charge and state of health, etc [7].

2. FUNCTIONS OF THE BMS

BMS takes care of the following things [8]:

- Battery charging and discharging rates
- Taking prevention in accordance with the cell voltage, temperature, and current.
- Estimating the state of charge and state of health
- Cell Balancing

A specific cell or group of cells known as a module is used for the continuous monitoring of the complete battery pack. The preferred choice for battery packs in a variety of consumer items is lithium-ion rechargeable cells due to their high energy density [8].

Indeed, while they work incredibly well, they can be relatively durable if used inside a safe operating area (SOA). If the battery performs outside of the SOA, it will suffer performance damage and potentially dangerous issues.

2.1 Current Protection:

Monitoring the current and voltages in the battery system is part of the electrical protection strategy. The electrical SOA of every battery cell is restricted by its current and voltage. As shown in Figure 1, BMS will safeguard the pack by limiting operation outside the specified cell ratings. In order to promote longer battery life, more de-rating may frequently be used to stay within the SOA safe zone.

A BMS that offers current protection will use a maximum continuous current. But, this could come before to account for a sudden change in the load conditions, such as the sudden acceleration of an electric vehicle. By combining the current and making a decision to either reduce the available current or stop the pack current altogether after delta time, a BMS can incorporate peak current monitoring. This enables the BMS to be tolerant of high peak demands as long as they are not excessive for an extended period of time, while simultaneously having virtually instantaneous sensitivity to extreme current peaks, such as a short-circuit condition that has not been detected by any resident fuses.

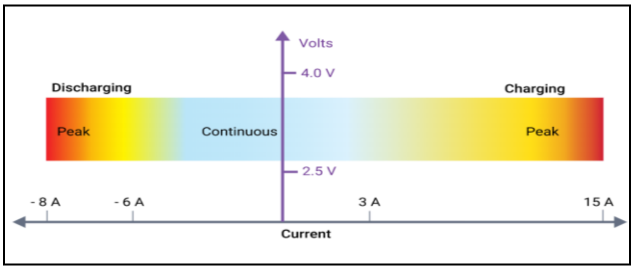

Figure 1: Current Protection

2.2 Voltage Protection:

A lithium-ion cell must function within a specific voltage range, as shown in Figure 2. The intrinsic chemistry of the chosen lithium-ion cell and the temperature of the cells at any given time will eventually decide these SOA bounds.

The BMS must be aware of these boundaries since it will issue orders based on how close a situation is to these limits. For instance, a BMS may ask that the charging current be reduced gradually as the high voltage limit is approached, or it may ask that it be stopped entirely if the limit is achieved. To avoid control chatter regarding the shutdown threshold, this restriction is typically complemented by additional intrinsic voltage hysteresis considerations.

Naturally, the BMS must prioritize the driver's safety above all else while safeguarding the battery pack to avoid irreparable harm.

2.3 Temperature Protection:

Although lithium-ion cells first appear to operate in a wide range of temperatures, their overall battery capacity actually decreases at low temperatures because chemical reaction rates are markedly slowed down.

During sub-freezing charging, the anode may experience the metallic lithium plating phenomenon. The cells' capacity is reduced as a result of this permanent damage, and they are also more inclined to fail under difficult circumstances such as vibration.

With heating and cooling, BMS may regulate the battery pack's temperature.

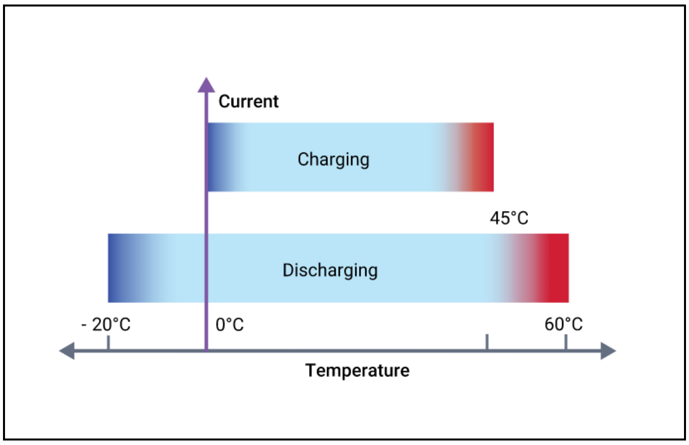

Figure 2: Temperature Protection

2.4 State-of-Charge Estimation:

The BMS's ability to monitor the battery's state of charge (SOC) is one of its features. The user could be alerted and the charging and discharging process could be managed by the SOC. There are three ways to calculate SOC: direct measurement, coulomb counting, and combining the two methods [6].

It is easy to determine the SOC directly with a voltmeter because the battery voltage declines almost linearly over the discharging cycle of the battery. The relative value of a battery's charge is calculated using the coulomb-counting method by integrating the current flowing into or out of the battery.

For the combining method, when the actual charge is getting close to either end, calibrate the SOC and a voltmeter can be used to monitor the battery voltage. In the meantime, the relative charge flowing through the battery might be calculated by integrating the battery current.

2.5 State-of-Health Estimation:

In contrast to other batteries, the state of health (SOH) is a measurement that assesses a battery's general health and ability to provide the necessary performance. The SOH of the cell can be determined using the impedance or conductance of the cell, both of which change considerably with ageing. In actuality, the SOH could be determined by taking just one reading of the resistance or conductance of the cell.

2.6 Cell Balancing:

Cell balancing is a technique used to compensate for weakened cells by balancing the charge on all of the cells to increase battery life. Weak cells may undergo excessive stress while being charged, weakening further until they ultimately fail, leading to an early battery failure. The BMS may use one of the three cell balancing strategies balancing, passive balancing, or the charge shunting method—to equalize the cells and prevent individual cells from getting overstressed while taking into consideration the lifecycle of the cells. During active cell balancing, charge is transferred from the healthier cells to the weaker cells. Dissipative methods are used in passive balancing to identify the pack's highest-charged cells, which are signaled by higher cell voltages. Once the voltage or charge is equal to the voltage on the weakened cells, the extra energy is then discharged through a bypass resistor.

First, the voltage of the cell in charge of shunting would be raised to its rated voltage. The current will stop charging the fully charged cells as soon as the cell reaches its rated voltage and continue charging the weaker cells until they reach their rated voltage.

3. BMS TOPOLOGY

Three basic topologies are used in the design of BMS hardware.

3.1 Distributed Topology:

In a distributed topology, each cell is equipped with a voltage meter, a discharge balancer, and a digital communications device that can shut off the charger and report on its state.

This construction has the benefits of being straightforward and highly reliable. The drawbacks include the need for a large number of printed circuit boards for mini-slaves and the challenge of mounting the boards on specific kinds of cells.

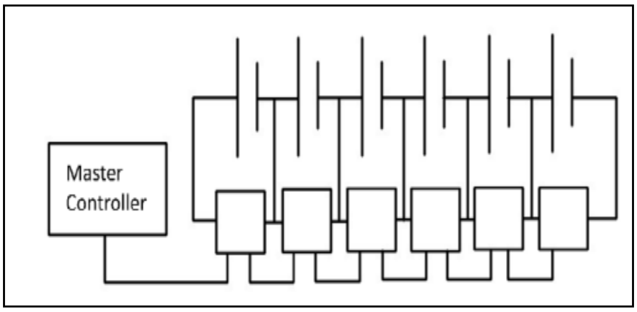

Figure 3: Distributed topology

3.2 Centralized Topology:

In centralized topology, each battery pack cell is immediately connected to a centralized master control unit. All cells are safeguarded and balanced by the management unit, which also serves a number of other purposes.

This topology doesn't need complicated inter-vehicle communications and only calls for one installation site. However, since the controller is the only source for cell balancing, too much heat might be produced. Additionally, the cells are dispersed throughout the car, necessitating wiring to a central location.

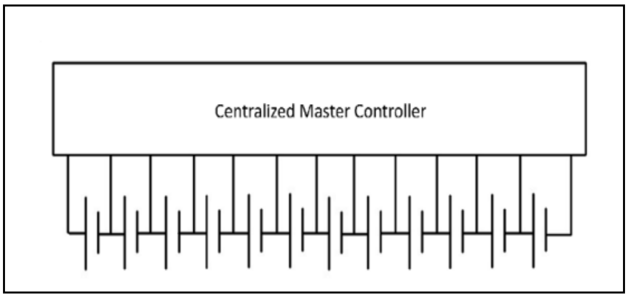

Figure 4: Centralized Topology

3.3 Modular Topology:

To consolidate the data to a master controller in the modular framework, several slave controllers are used.

The separate cells can be connected without printed circuit boards. However, when this structure is used in electric vehicles, it is challenging to accomplish isolated master-slave communications.

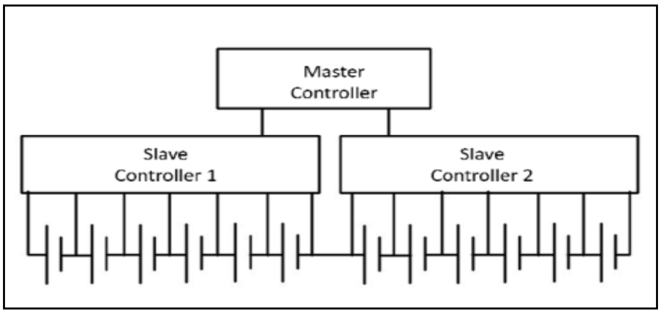

Figure 5: Modular Topology

Modular topology can be designed using three interfaces:

3.3.1 CAN Interface

3.3.2 SPI Interface

3.3.3 Wireless BMS

3.3.1 CAN Interface:

The CAN interface is used to establish communication between the master and slave.

Given CAN bus' success in automotive uses, it offers a practiced network for connecting battery modules but needs a number of extra parts. The communication is established using the SPI interface.

The installation of an isolated CAN network via an SPI interface requires a CAN transceiver, a microprocessor, and an isolator.

The main drawback of a CAN bus is the extra expense and boards needed for these extra components.

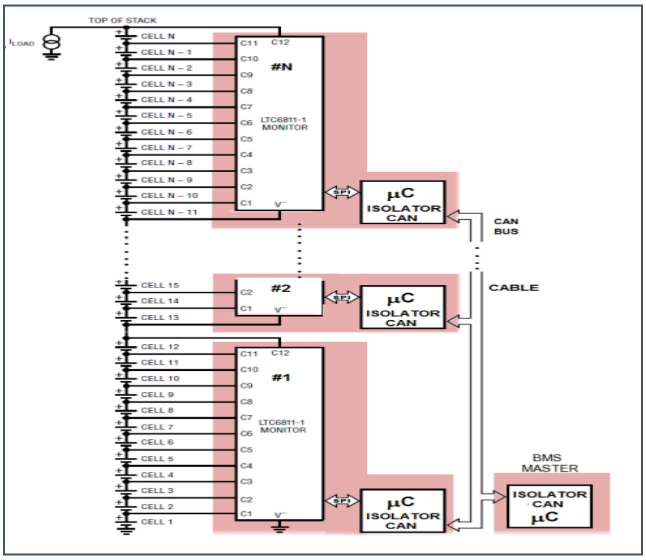

Figure 6: Modular BMS using CAN Interface [10]

3.3.2 SPI Interface:

2-wire isoSPI can be used instead of CAN Bus interface. The CAN system requires four wires, whereas the isoSPI interface only needs a single twisted pair and a transformer.

The isoSPI interface offers a high RF noise immunity interface that enables daisy-chaining of modules over lengthy cable lengths and data rates of up to 1Mbps.

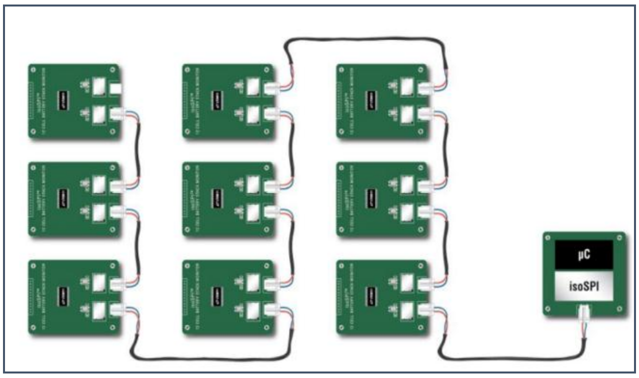

Figure 7. Modular BMS using using isoSPI Interface [10]

3.3.3 Wireless BMS:

Instead of using CAN Bus cables or isoSPI twisted pairs to link the modules, a wireless connection is used in a wireless BMS.

The conventional wired connections between the battery packs and the battery management system are replaced in this wireless BMS prototype vehicle by a master board controller and a wireless network manager. All communication between the host controller and the network manager will be carried out via isoSPI. Following that, a wireless connection between the network controller and the slave boards will be established. Wireless contact between the network manager and slave boards can be established using an RF antenna.

The wireless network manager allows for the flexible placement of battery modules and makes it possible to put sensors in places where a wiring harness was previously unsuitable.

Sensors like SmartMesh can provide the BMS Master with additional information like current and temperature for use in battery state of charge (SOC) computations. With the use of these sensors, readings at each node will be properly timestamped and each node will be automatically time-synchronized within a couple of µs.

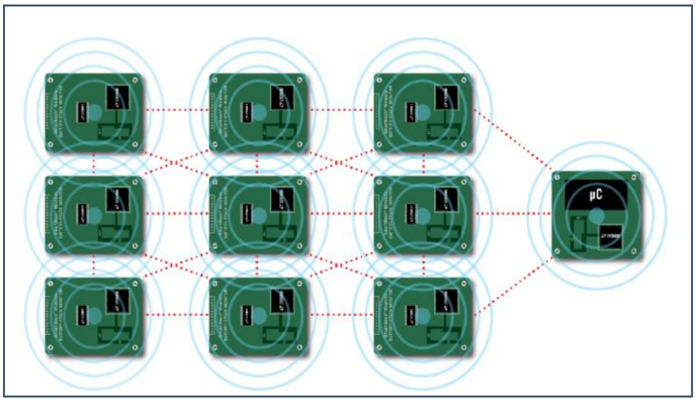

Figure 8: Modular BMS using a wireless communication protocol [10]

4. 1 Software Architecture of Wireless BMS:

Different tasks can be completed concurrently and without interruption in the software architecture. The initial duties of a BMS software architect, including voltage and current measurement, overcurrent and voltage protection, temperature monitoring, and protective relay actuation, must be completed right away to guarantee BMS safety. Three layers make up most software development: the HAL layer, the base software, and the application software.

The link between the operating system's higher layers and the underlying hardware is provided by HAL.

Base software includes a driver development framework for microcontrollers. MATLAB is used to implement all of the BMS functionality-related strategies in the application layer.

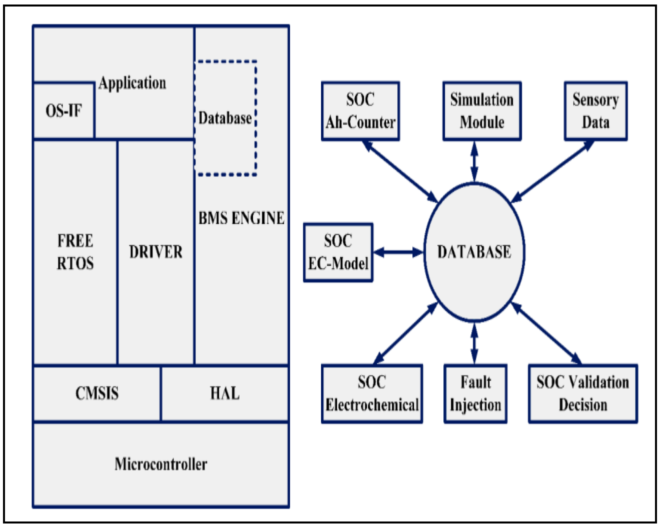

Figure 9: Software Architecture of WBMS

4.2 Benefits of Wireless BMS:

• Wireless battery-management systems (WBMS) have the potential to further increase the safety and dependability of the entire battery system by continually monitoring battery packs for the state of health (SOH) and state of charge (SOC). By switching to a wireless battery-management system, the car's driving range can be increased while maintaining the same level of energy efficiency due to the system's lighter weight.

• In addition, a common cause of cable failures is the wire harness and connectors. Because they do not require physical harnesses or wires, wireless BMS should result in lower end-user repair costs. By allowing the replacement of a battery module rather than the entire battery's internals, maintenance is also made simpler.

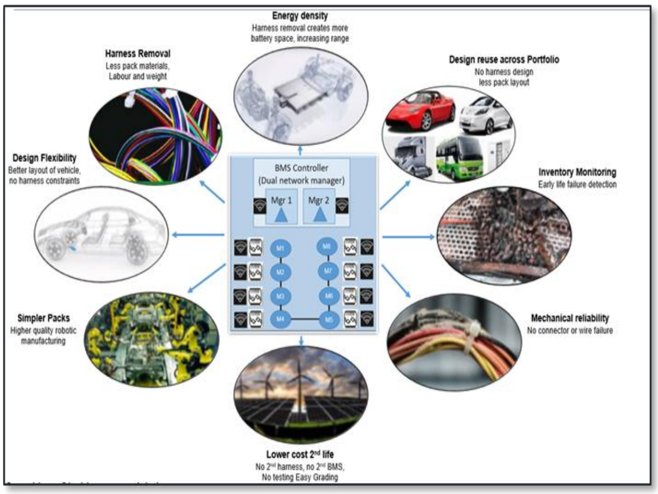

Figure 10: Benefits of BMS

Conclusion:

The primary objective of this paper is to perform a thorough review of battery management systems.

In this paper, we addressed the various BMS functions, including cell balancing, SOC, SOH estimation, temperature protection, voltage protection, current protection, and temperature protection.

The different BMS topologies and communication interfaces, such as SPI, CAN, and wireless BMS, were also mentioned.

Expanded BMS capability is made possible by wireless BMS.

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