Battery Management Systems for Electric Vehicles

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Abstract: -The fast progress of electric vehicle (EV) tech has brought big changes to cars. One important thing making this happen is the Battery Management System (BMS). Companies like Audi, Nissan, and Porsche are spending a lot on research to make these systems better, aiming to make them work even cooler. BMS is like a smart brain with sensors in EVs. It helps keep the power steady by watching the battery closely. Smart people are working to make BMS even smarter, especially at knowing how much battery is left. This upgrade could make EV batteries work better and last longer. The goal is to make EVs cooler and help the planet. If BMS can tell exactly how much battery is left, EVs can use power even better. This means driving can be smoother and the battery can stay strong for a long time. That's good because it makes people want EVs more. And when smart BMS is used, less pollution goes into the air, which is good for the world.

Key Words: — ***BMS, EVs, Sensors, Smart Brain.***

I. Introduction

In India, vehicles contribute to about 27% of air pollution, ranking as the second-largest source after industrial activities. Furthermore, vehicles in India account for approximately 8% of the nation's total greenhouse gas emissions. Taking steps to curb vehicle emissions, promoting cleaner technologies, and advocating for sustainable transportation practices are pivotal actions to address air pollution and combat climate change. With the growing dependence on public and personal transportation in India, the daily aggravation of air pollution has become a pressing concern. Consequently, electric vehicles are gaining traction as a cleaner and more sustainable solution.

In the Indian context, an electric vehicle consists of several essential components. These include an electric motor, a motor controller, a traction battery, a battery management system, an independent plug-in charger, a wiring system, regenerative braking, and a vehicle body with a frame. Among these elements, the battery management system plays a vital role, particularly when employing lithium-ion batteries.

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India provides three types of traction batteries for electric vehicles: lead-acid, nickel-metal hydride, and lithium-ion batteries.[1]. Among these options, lithium-ion batteries exhibit numerous advantages over the other two types, especially when paired with an efficient battery management system.[2]. The primary objective of the Battery Management System (BMS) is to ensure the cells operate within their designated safety parameters. This critical task is achieved by incorporating various safety mechanisms, including protection circuits and thermal management systems.

II. BMS For Electrical Vehicle

Battery Management Systems (BMS) are meticulously crafted to offer comprehensive functionality and seamless integration within vehicles, ensuring the battery system operates efficiently and reliably. In addition to core responsibilities like battery monitoring, protection, and thermal management, the BMS undertakes a variety of supplementary tasks to enhance overall performance and safety.

A pivotal role of the BMS is to uphold the battery's State of Charge (SOC) and State of Health (SOH). Employing sophisticated algorithms and models, the BMS accurately estimates the battery's remaining capacity, enabling precise tracking of energy levels. By continually assessing SOC and SOH, the BMS empowers the vehicle's power management system to optimize battery usage, guaranteeing dependable performance throughout the vehicle's operation.[3]

Moreover, the BMS encompasses advanced features that bolster battery longevity and counteract degradation. Employing methods like cell balancing, the BMS redistributes charge among individual battery cells to maintain uniform cell voltage levels, thus preventing capacity imbalances. This balancing procedure maximizes overall battery pack capacity utilization and extends its lifespan.

Another critical facet of the BMS is its adeptness at effectively regulating the charging process. By overseeing parameters like charging current, voltage limits, and charging algorithms, it ensures safe and efficient charging, circumventing scenarios of overcharging or undercharging that could detrimentally impact battery performance and lifespan.[4]

Integration with other onboard systems is a pivotal dimension of the BMS. Through interaction with the motor

controller, the BMS optimizes power distribution based on the vehicle's power requirements, enhancing overall efficiency and performance. Additionally, the BMS communicates with the climate controller to maintain thermal conditions within acceptable thresholds, averting excessive heat accumulation and sustaining optimal battery operating temperatures. Integration with the communications bus enables seamless data exchange with other vehicle systems, enabling real-time monitoring and control.

Safety takes precedence in BMS design. It incorporates attributes such as fault detection, isolation, and emergency shutdown mechanisms to safeguard against hazardous situations or malfunctions. Continuously scrutinizing the battery system for irregularities, the BMS triggers suitable responses to protect both the battery and vehicle occupants.

The BMS functions as an integral component of a comprehensive power management system within a vehicle, ensuring the battery's optimal operation and safety while seamlessly integrating with other essential onboard systems.

The specific duties of a Battery Management System (BMS) can vary based on the particular application. However, the core functions of a BMS are as follows:

- Optimization of Battery Energy
- Minimization of Battery Damage Risk
- Monitoring and Control of Charging and Discharging

By fulfilling these essential tasks, the BMS assumes a pivotal role in maximizing the utilization of battery energy, shielding the battery from potential harm, and maintaining precise control over the charging and discharging sequences. This, in turn, enables the efficient and dependable operation of products and systems powered by batteries while upholding the battery's durability and performance over time.

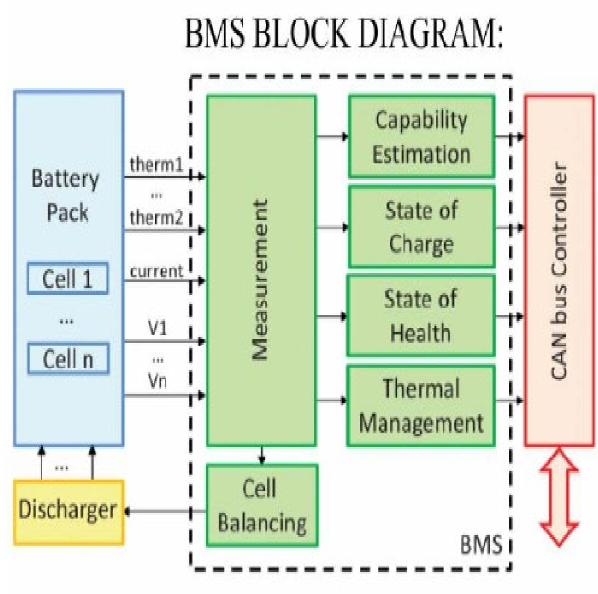

Fig.1. Block Diagram of BMS

III. BMS MODELING

The primary purpose of the Battery Management System (BMS) is to optimize the charging of batteries in electric vehicles. This requires a detailed simulation of the vehicle's power system and an accurate battery model. This model considers factors like battery chemistry, capacity, voltage, internal resistance, and temperature behavior. With this model, the BMS can make informed decisions about how to charge and discharge the battery, leading to better overall management and efficiency.

Battery modelling involves the following steps

3.1 SoC Estimation

State of Charge, is a measure of how much charge is left in a battery compared to its full capacity.

SoC is crucial to make sure the battery is never undercharged (which can harm it) or overcharged (which can be dangerous).

$$SoC(t) = \frac{Q(t)}{Qn} \quad (1)$$

Where is Q(t) is current capacity of the battery, Q_n is nominal capacity of that same battery.

SoC helps the battery management system decide if the battery is in good condition and keeps it working safely.[5].

It's an important parameter that tells us about the battery's performance.

Getting SoC estimation right not only protects the battery and makes sure it lasts longer by preventing overcharging, but it also helps us make smart decisions to save energy.

However, accurately estimating SoC is quite complex and challenging because of the limited battery models and uncertainties in their characteristics.[6].

3.2 SoH Estimation

State of Health (SoH) estimation measures a battery's health compared to a new one. It tells us how much power it can provide over its life. For electric vehicles (EVs), SoH relates to driving distance or range. It's also used in hybrid vehicles for starting power from regenerative braking. Battery health is often considered good if it's above 80% of its original capacity. Researchers and manufacturers use this threshold. Battery failure happens when capacity drops to 80% after charging and discharging cycles.

To assess SoH, experts use various factors like capacity and power fade. Capacity fade reduces driving range, while power fade affects acceleration. Researchers like Pattipati et.al.[7] combine these health factors. They used a model called auto-regressive Support Vector Regression (SVR) to calculate SoH. As batteries age, power loss occurs due to increased cell impedance.

3.3 Thermal Management

Maintaining an optimal temperature for battery cells is crucial for enhancing EV performance. Elevated temperatures can trigger harmful reactions, leading to thermal runaway. Above 90 degrees Celsius, battery components start to break down. $LiFePO_4$ batteries show better thermal stability.[8] A mere 1-degree Celsius rise in temperature within 30-40 degrees Celsius can reduce battery lifespan by two months. Efficient heat management is vital, requiring research for suitable cooling and heating systems.

Sub-zero temperatures decrease battery efficiency, affecting vehicle mobility and range. For instance, the 2012 Nissan Leaf's range dropped from 138 miles to 63 miles at 10°C. Since pure EVs lack combustion engines for heating, significant energy is needed to warm the battery and cabin, reducing range by 30-40%.

To ensure optimal BMS performance, a Thermal Management System (TMS) maintains battery temperature within a safe range. TMS responds swiftly to excessive temperature, employing heating and cooling mechanisms for safety and control.

TMS uses air or liquid for heating/cooling. Air TMS offers passive and active cooling/heating, while liquid TMS offers passive/active cooling and heating, excelling in heat capacity and conductivity. An electronic control unit manages TMS operations.[9]

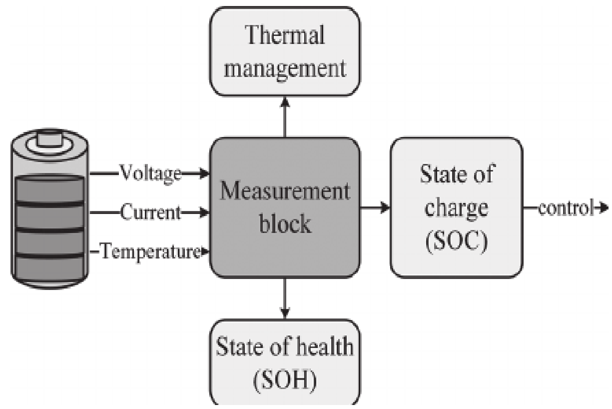

Fig.2.SoC, SoH, Thermal Management

3.4 Cell Balancing

Battery cells within a pack can differ in chemicals, charge capacity, and external impacts. Series-connected cells undergo varied charge and discharge rates, leading to unequal state-of-charge. Voltage and capacity differences emerge, reducing cell capacity and battery lifespan. An auxiliary balancing circuit in the battery management system resolves this energy imbalance.[10]

3.4.1 Passive Cell Balancing

Resistors are commonly used to balance cell energy passively by allowing more energy in certain cells. This method is dependable and requires fewer components than other methods. It discharges cells by creating a dissipative path. Passive balancing is simpler and more cost-effective, but less efficient as extra energy is wasted as heat during discharge.

3.4.2 Active Cell Balancing

Active balancing uses energy-transfer devices like capacitors or inductors to balance cell energy. It's more effective and quicker than passive balancing, but costs more and demands advanced control algorithms. Active balancing transfers charge between cells using inductive or capacitive methods, effectively using energy rather than wasting it. However, it adds components and increases costs.[11]

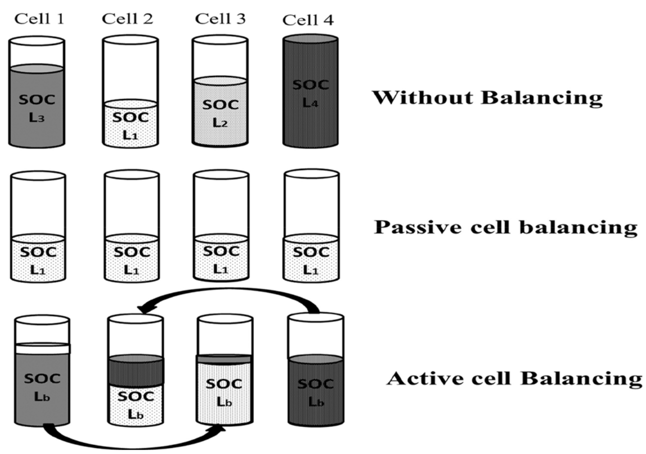

Fig.3. Cell Balancing

IV. Results And Discussion

This study aims to enhance the battery management system (BMS) for electric vehicles by integrating all steps to accurately estimate state of charge. BMS monitors various parameters for battery safety and endurance, requiring proper linking of components in a specific order and location.

MATLAB SIMULINK is a user-friendly tool for building BMS, including crucial cell balancing for accurate state of charge estimation. BMS acts as an embedded system in many cars, providing real results and simulations, though these methods are theoretical.

After studying existing models, we discuss the required components and method to create such an electronic device. The final BMS design features a dashboard with LED lights to display errors related to current, temperature, and voltage during electric vehicle charge and discharge. It includes a rotating switch with three modes (Balanced, Charging, and Driving) to alert the driver about battery pack errors.

This study introduces an enhanced battery model and an innovative BMS hardware setup. The battery model considers common battery effects like self-discharge, temperature, and capacity fading.

Simulations in Matlab/Simulink are discussed. The BMS hardware system adds a user interface, thermal management, and current monitoring to the original system. Experimental results are analyzed and compared to simulated Thundersky battery outcomes.

Future directions include validating the battery model with diverse battery data, enhancing the BMS with fault detection, and using simulations to optimize the BMS and battery management methods.

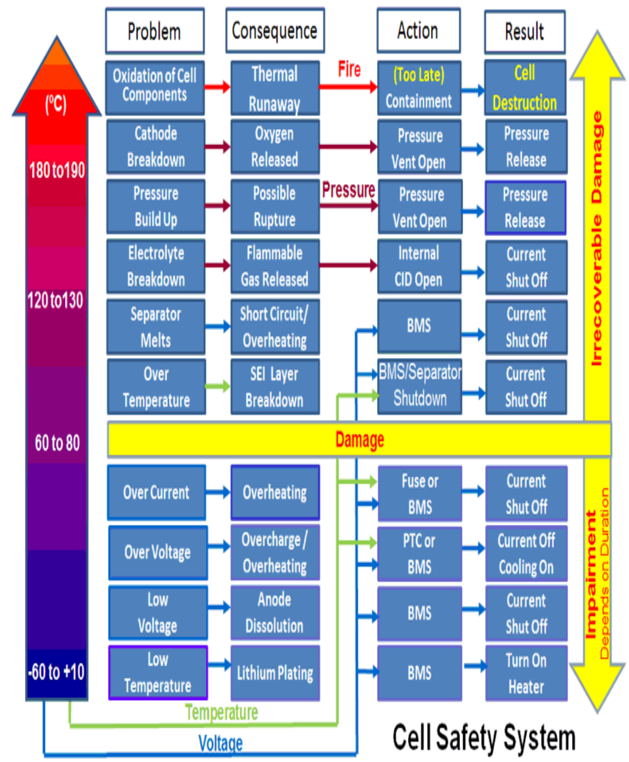

Fig.4. BMS Benefits

V. Conclusion

In recent decades, the availability of vast amounts of data, powerful computational processors, and high-capacity data storage devices has facilitated extensive exploration and advancement of intelligent algorithms and control techniques within Battery Management Systems (BMS) for Electric Vehicles (EVs). This paper conducts a comprehensive examination of the current landscape of intelligent algorithms for State of Charge (SOC) estimation, with a specific focus on their structural design, input features, advantages, disadvantages, and estimation accuracy, representing an initial contribution to the field.

In conclusion, the meticulous analysis and valuable insights derived from this review are poised to greatly benefit automotive engineers and the EV industry at large. These findings will contribute to the development and successful implementation of sophisticated BMS solutions tailored for EV applications. Consequently, further research and innovation in BMS leveraging intelligent algorithms and controller strategies stand to enhance not only battery performance and longevity, but also ensure the secure and reliable operation of electric vehicles. This, in turn, will drive substantial growth within the battery and electric vehicle markets. The expansion of these markets aligns with the pursuit of sustainable development goals, encompassing objectives such as clean energy promotion, pollution reduction, job creation, and overall economic progress.

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