BMS Monitoring and Fire Protection for Electric Vehicles

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Abstract

Many car makers have developed electric vehicles that are available in both two-wheelers and four-wheelers. Thus, the battery becomes an important component and improves the methods for calculating the load capacity of the vehicle. An effective battery management system must be created and developed so that they do not overcharge or deep discharge. Accurate assessment of the state of charge of electric vehicles reduces the risk of damage, extends their service life and protects the electronics used. This project proposes a real-time battery monitoring system (BMS), which uses the method of Charge (Soc) and displays important parameters. The proposed BMS is implemented on a hardware platform using an Arduino environment, suitable sensor technology, processor and interface device.

Keywords: *- Framework are BMS Key, Cell Equality, Charge Estimations, Control, and Bluetooth Module.*

1. Introduction- Gas prices rise, the popularity of electric vehicles (EVs) is increasing. This trend has led many car manufacturers to look for other sources of gasoline power. Using renewable energy sources helps the environment because it causes less pollution. Electric vehicles offer significant benefits for protecting the environment and increasing energy efficiency. Electric vehicles usually use rechargeable lithium-ion batteries. It is smaller in size compared to lead acid. In fact, these batteries produce electricity continuously and have an energy life cycle 6 to 10 times longer than lead-acid batteries. The longevity of a lithium-ion battery can be reduced by several factors, including poor disposal and high cost. On the other hand, the operating range of electric vehicles (EVs) is limited by the size and shape of the battery and body. Currently, concerns about the safety of battery technology are severely limiting the adoption of electric vehicles. For example, overcharging the battery can not only shorten the life of the battery, but also cause safety hazards such as fire[1] . Therefore, to avoid the aforementioned problems, electric vehicles must have a monitoring system that can inform the user about the state of the battery. Previous battery monitoring systems did little more than track and detect the. battery status while the user is moving using the vehicle's battery indicator. This technology allows manufacturer s and users to be notified of battery status when building an advertising system. This is considered one of our mai ntenance support services. This is a process that developers can do. In this study, considering the above problems , we will consider the design and implementation of a battery monitoring system using an integrated system. The capacity vitality powers EV embellishments, the lighting framework, the engine, and different operational components. The rechargeable ESDs, e.g., Li-ion battery (LIB), lead-acid battery, SCs, and nickel and zinc batteries, are utilized in EVs. The innovative advancement of ESD has caused an strong increment in ESD demand within the field of versatile electrical devices. In any case, lead-acid batteries have as of late had a broad around the world advertise in sun-powered ESSs, while the LIB has future in bulk ESS. Distinctive sorts of ESDs are considered based on particular necessities in EVs In EV frameworks, ESD [2]details account for person cell security, particularly vitality capacity capacity. The cell voltage [3] of an ESD gets imbalanced due to the battery administration framework (BMS), which is obligatory for an ESS, and plays an imperative part in EVs, as appeared in Figure 1. The BMS guarantees the ESD's long-lasting benefit, security, and adjusted office for EV driving. The BMS is a broad structure containing comprehensive instruments and execution evaluation for various ESD sorts, cell observing, control, warm administration, charging/discharging strategies, well-being status, information acquirement, cell security, and lifetime. Cell voltage lopsidedness happened amid the charging/discharging time for inner electrochemical responses in ESD. In BMS, cell voltage adjusting is the driving work to progress cell life span and security. Analysts and researchers are working on BMSs to create profoundly productive cell voltage/charge

[1] Gholami, K.; Azizivahed, A.; Arefi, A. Risk-oriented energy management strategy for electric vehicle fleets in hybrid AC-DC microgrids. J. Energy Storage 2022, 50, 104258.
[2] Barbosa, W.; Prado, T.; Batista, C.; Câmara, J.C.; Cerqueira, R.; Coelho, R.; Guarieiro, L. Electric Vehicles: Bibliometric Analysis of the Current State of the Art and Perspectives. Energies 2022, 15, 395.
[3] Habib, A.A.; Hasan, M.K.; Mahmud, M.; Motakabber, S.; Ibrahimya, M.I.; Islam, S. A review: Energy storage system and balancing circuits for electric vehicle application. IET Power Electron. 2021, 14, 1–13.

adjusting frameworks to adjust the cell voltage/charge, secure the cell from unsafe blasts, and move forward its unwavering quality.

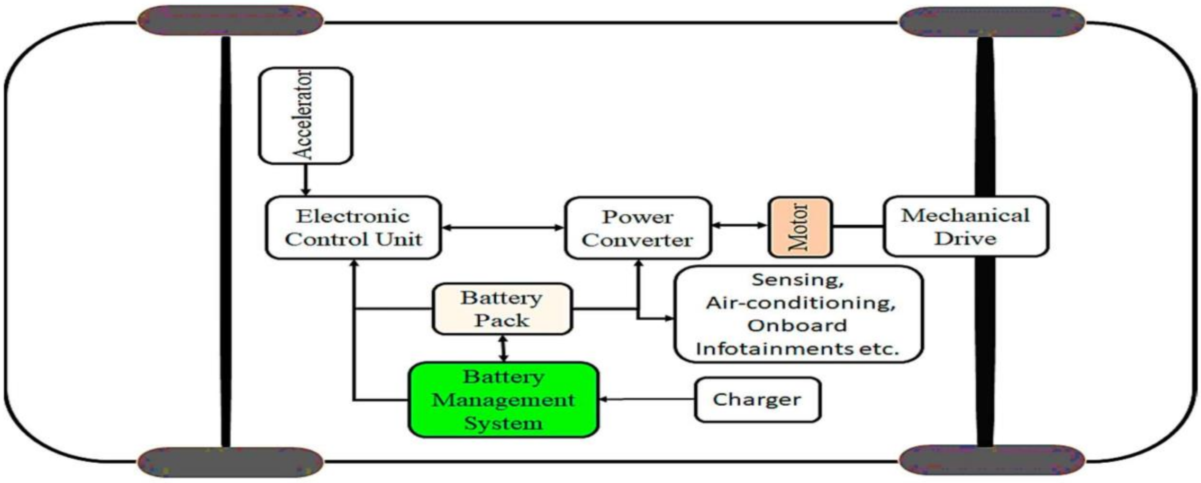

Figure 1. BMS operation inside the EV.

Much inquire about has been conducted on the BMS working situations for EV frameworks. The BMS field makes more consideration and increases the inquiry about scope at the scholastic or mechanical level. The noteworthiness of BMS inquire about is outlined in Figure 2, where we show the number of distributions since 2010. Shen and Gao analysed BMSs based on modelling endeavours. Lelie et al. checked on BMS equipment concepts. In, there's a discourse of battery modelling and state-of-charge estimations. Lin, Jiayuan, et al., looked into battery warm administration frameworks LIB and See, K.W. et al., looked into security[4] issues on BMSs on an expansive scale LIB. Tran, Manh-Kien, et al., checked on cloud-based shrewd BMSs for LIB. In any case, most of the ponder centred on BMS-specific parameters (i.e., battery modelling, state-of-charge estimation, voltage adjusting, warm, security, etc.), for which a few focuses are still missing. Considering these missing focuses, the essential objective of this consideration is to display a brief overview and to summarize the existing BMSs, depictions, issues, challenges, and suggestions based on different researchers' endeavours. This think about begun with the foundation on ESSs, BMSs, and EV-applicable batteries. At that point, a brief diagram of BMSs, their issues, and challenges are displayed. At last, the viewpoint of BMS advancement for a long-standing time is displayed.

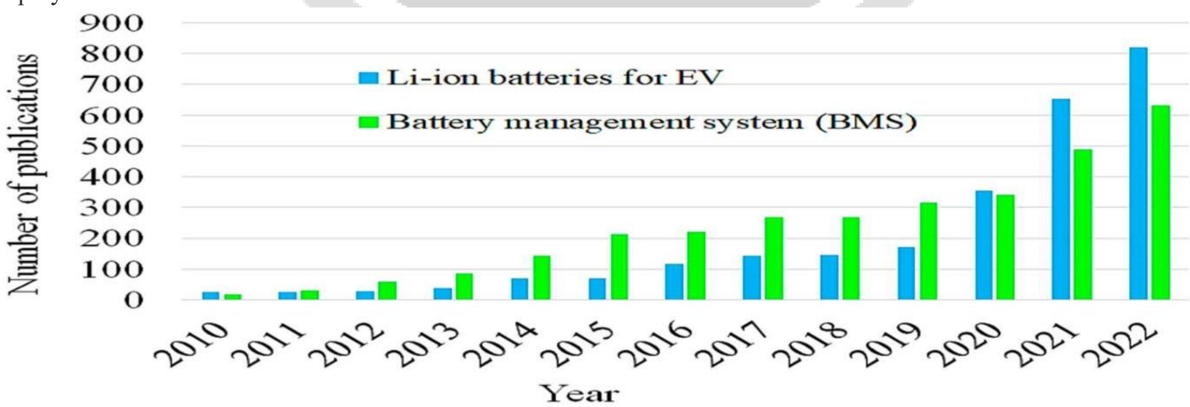

Figure 2. Battery management system, adapted from

[4] Chen, M.; Zhang, Y.; Xing, G.; Chou, S.-L.; Tang, Y. Electrochemical energy storage devices working in extreme conditions. Energy Environ. Sci. 2021, 14, 3323–3351.

2.Battery- A battery is an electrochemical energy storage device that provides electrical energy. EVs use secondary electrochemical batteries that offer increased power and energy. The automation/EV sector has been greatly influenced by the technological progress in batterie. Scientists have continuously been improving the EV battery system to offer more powerful and higher energy-density batteries. High-capacity batteries with increased energy and power density, prolonged lifespan, and resistance to high temperatures are used in electric vehicles (EVs)[5]. Different rechargeable batteries like nickel-based batteries, LIBs, and sodium–sulfur-based batteries are utilized in electric vehicles (EVs) LIBs have an energy density of 0.3 MJ/kg, which is significantly lower than gasoline's 48 MJ/kg, but are still viable option for EV use. Currently, lithium-ion batteries (LIBs) are the most commonly used system in electric vehicles (EVs).LIBs are commonly used in consumer products, electric vehicles, and grid energy storage. Materials that can be used as positive[6] electrodes include lithium metal oxide ($LiCoO_2$, $LiNiO_2$, $LiMn_2O_4$) and lithium iron phosphate ($LiFePO_4$). Graphite is commonly utilized in the negative terminals. The electrolyte consists of a lithium salt that is not dissolved in water. A $LiPF_6$ separator is utilized for electrical insulation. LB provides a high energy density, specific energy, durable lifespan, efficient cycling, rapid response time, and low individual discharge rates. The expensive cost and potential dangers of overcharging limit the use of Li-ion batteries in the power industry.

3.Battery Management- LIBs are increasing in strength and providing electric vehicle propulsion as a substitute for traditional internal combustion engine cars in environmentally friendly transportation all over the globe. HEV and BEV technologies will have a beneficial impact on the global economy and the environment. Devices in EV technologies must improve their effectiveness during operational hours and ensure safe operation, as well as protect the ESS. The Battery Management System (BMS) oversees various functions such as energy storage, transmission, control, and management facilities for electric vehicles. It also handles tasks such as charge equalization, battery cell voltage control, input/output voltage controls, protection, and diagnosing and assessing errors. Figure 5 contains certain specifications and functions of the BMS. The battery charging characteristics and status are also controlled by the BMS. The BMS manages the battery's charging, discharging, and the battery pack's power needs. The Battery Management System (BMS) monitors the voltage levels of lithium cells and prevents them from being overcharged or undercharged. In order to enhance battery performance and lifespan[7], the BMS needs to implement cell balancing methods utilizing charge voltage equalization. The Battery Management System (BMS) monitors the temperature of the cell during certain phases, controls a power converter, and ensures the battery cell remains in good health and operates safely in high temperatures. The cell protection mechanism safeguards the cell against issues such as short circuit, overload, and current/voltage stress as time goes on [30,31,32]. In the electric vehicle system, the battery management system evaluates and assesses the energy storage allocation procedures and faults. The current and voltage monitoring in the LIB cell, estimation and protection of LIB charge/discharge control, cell equalization, temperature, power, and heat management, data storage and acquisition, communication and networking, and fault assessment and diagnosis are all part of the specifications.

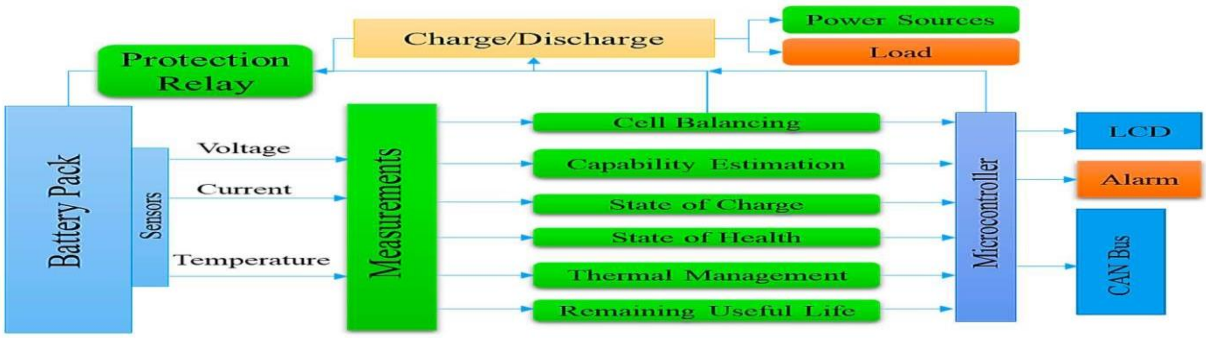

Figure 3. Battery management system, adapted from

[5] Ravi, S.S.; Aziz, M. Utilization of Electric Vehicles for Vehicle-to-Grid Services: Progress and Perspectives. Energies 2022, 15, 589.
[6] Chen, M.; Zhang, Y.; Xing, G.; Chou, S.-L.; Tang, Y. Electrochemical energy storage devices working in extreme conditions. Energy Environ. Sci. 2021, 14, 3323–3351
[7] Sumdani, M.G.; Islam, M.R.; Yahaya, A.N.A.; Safie, S.I. Recent advancements in synthesis, properties, and applications of conductive polymers for electrochemical energy storage devices: A review. Polym. Eng. Sci. 2022, 62, 269–303.

4.1 Current and Voltage Monitoring- Electric vehicles are tightly linked via lithium-ion battery packs. The battery cells may vary in nature during operation. p cell monitoring is crucial in order to assess the condition of the cells. The results of cell monitoring influence the device's energy management, power delivery, and safety efficiency. It oversees cell monitoring during discharge and charge, providing protection against overcharge and undercharge, monitoring temperature and heat, detecting faults[8], handling data acquisition interface, connecting devices, and conducting evaluations, among other function. LIBs provide steady voltage and current throughout the discharging period. The cell damage or explosion is caused by the fluctuating current and voltage delivery in the cell. While in use, it is important to control the voltage and current levels of the cell to prevent it from being undercharged or overcharged. Furthermore, the voltage and current status of the battery pack are shown for additional support.

4.2 Cell Equalizing Battery Energy Storage Systems (BESSs)- Electric vehicle are being more commonly utilized in Electric Vehicle (EV) applications because of their numerous beneficial features, like quick response to demand, versatile installation options, and short construction period. As a result, BESS has a beneficial impact on the electrical power system by supporting functions such as voltage and frequency regulation, black-start capability, standing reserve, integration of renewable energy, peak shaving, load levelling, and enhancing power quality. BESS cells are connected in a series or parallel arrangement within the strings[9] to meet the necessary power requirements. Cells often have a SOC imbalance in BESS because of either an internal or external cause and effect. Cell imbalances are caused by manufacturing defects, self-discharge rate, internal impedance, and charge storage volume. The uneven spread contributes to the rise in temperature in a BESS, caused by diverse self-discharges during the state of charge and discharge cycles in cells with varying strengths. Various methods for balancing cells have been suggested over the past few decades. Those can be divided into two primary groups: active balancing and passive balancing, depending on their ES elements, usage, and energy balancing techniques demonstrated in

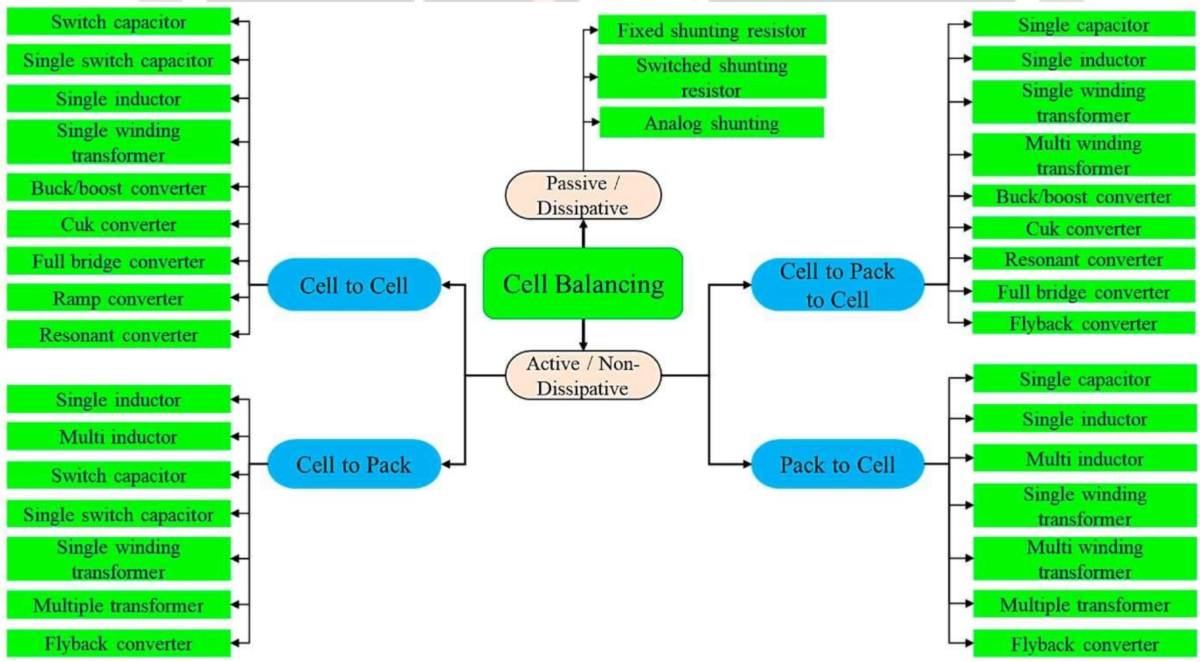

Figure 4. Cell balancing topol

4.3 Temperature Management Balanced and efficient- Power distribution is the recent challenge on EVs, whereas minimal power loss and abuse take advantage. Without power management, the overall system performance is reduced. Besides that, different types of electronic equipment, irregular operation in equipment and machinery, and unreliable power supply are the reasons for the lower effectiveness of the BESS. Managing the stabilized power supply and power control during the charging time of EVs using a management [10]system and power control is an intelligent and highly beneficial method. Considering SOC, SOH, and aging, optimal power

[8] Lelie, M.; Braun, T.; Knips, M.; Nordmann, H.; Ringbeck, F.; Zappen, H.; Sauer, D.U. Battery management system hardware concepts: An overview. Appl. Sci. 2018, 8, 534.

[9] Li, S.; Fan, Z. Encapsulation methods of sulfur particles for lithium-sulfur batteries: A review. Energy Storage Mater. 2021, 34, 107–127.

[10] Okay, K.; Eray, S.; Eray, A. Development of prototype battery management system for PV system. Renew. Energy 2022, 181, 1294–1304. v

regulation and management are required to maximize system protection, longevity, and efficiency. It decreases power loss and maintenance of the automated control and administration of EV systems. An ESS's temperature control component keeps the LIB within thermal range. It regulates heating and cooling. To prevent explosions, the EV battery's temperature is constantly monitored. The LIB pack must be compatible with the EV. The BMS controls onboard cooling and heating systems

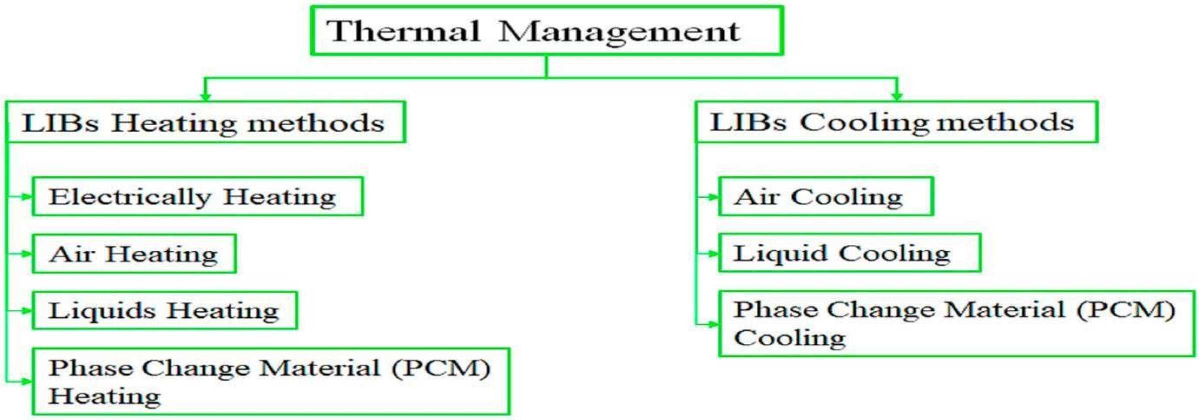

Figure 5. Taxonomy of thermal management system.

5.Issue And Challenge Lithium-ion batteries- Possess various characteristics such as large capacity, high power and energy density, good tolerance to high temperatures and cyclic life, extended duty cycle, rapid charging, and reduced memory effect. Nevertheless, certain concerns need to be addressed, necessitating[11] the identification of suitable remedies for safety sensitivities, recycling and environmental effects, unique and costly attributes, and the memory effect during discharge and charging periods in various consecutive applications. The same problems can also affect other types of electrochemical batteries used for electric vehicle purposes. Below are brief overviews of the primary issues.

5.1 Battery Models BMS- Batteries are typically characterized using physical (equivalent, electrochemical) and data-driven (hybrid) techniques. Testing in different environments is impossible due to the need for precise conditions. Data-driven algorithms' performance and [12]computational complexity highly depend on test data and training procedures. It has resulted in several clever techniques/algorithms

5.2 Thermal Run Away- In order to achieve accurate measurements of SOC and RUL and avoid system breakdowns, BMS depends on gathering temperature data from various sources both on-site and off-site. Nevertheless, an intelligent BMS depends on precise, affordable temperature sensors and covers a broad range of temperatures, with a focus on monitoring indoor temperatures. Charging one cell above the standard industry voltage (4.35 V) and raising the charging and discharging frequency both contribute to the irreversible chemical process. Possible adverse effects consist of lithium plating, overcharging, short-circuiting, and heat accumulation. Charging at a faster rate increases the likelihood of thermal runaway, leading to an explosion[13].

5.3 Battery Charging And Discharging -BMS also faces issues due to the absence of standard battery chargers. Personalized battery chargers are typically smaller and designed for household use, resulting in more electrical mess and waste in the environment. Due to the extensive range of batteries being utilized, designers of battery chargers are required to address this matter. Using safe–discharge batteries is necessary when dealing with damaged or old batteries, as they can pose a danger. Batteries submerged in saltwater create hydrogen and oxygen gases which need to be released to prevent explosion. Releasing batteries with resistors necessitates a small current to avoid excessive heat buildup.

[11] Surya, S.; Williamson, S.S. A Comprehensive Study on DC–DC and DC–AC Converters in Electric and Hybrid Electric Vehicles. In E-Mobility; Springer: Berlin/Heidelberg, Germany, 2022; pp. 59–81

[12] Lin, M.; Xie, H.; Shan, M. A Hybrid Multiscale Permutation Entropy-Based Fault Diagnosis and Inconsistency Evaluation Approach for Lithium Battery of E-Vehicles. IEEE Access 2022, 10, 104757–104768.

[13] Mc Carthy, K.; Gullapalli, H.; Kennedy, T. Real-time internal temperature estimation of commercial Li-ion batteries using online impedance measurements. J. Power Sources 2022, 519, 230786.

5.4 Recycling and reusing batteries-Another concern that needs to be addressed is the recycling of batteries. There is a need for a system to gather and reuse batteries to cope with the increasing number of used LIBs. Moreover, it will reduce environmental problems and increase opportunities for recycling. Nonetheless, no established process has the least impact on the environment.[14] Another issue facing BMSs is the recycling of batteries. Battery characterizations conducted in labs, which are limited to just one use, are heavily trusted by BMS algorithms. The electrochemical characteristics of the batteries alter over time due to usage and exposure to varying environmental conditions. Hence, it is not advisable to presume that aged batteries possess identical traits to fresh ones. Metals such as copper, aluminium, and cobalt can also be discovered in batteries. Because of the increased extraction of metals used in batteries and the subsequent increase in prices, it would be beneficial to be able to reuse these batteries. Currently, retired batteries in large quantities are being utilized globally for the refurbishment of energy storage systems and various applications. The BMS is crucial for ensuring the safe operation of second life-cycle batteries[15].

6. Recommendation Sustainable research and development scopes for the future of EVs are recommended and emphasized, focusing on issues and challenges. The future of LIB manufacturing and technological advancement has been achieved in the following manner:

6.1 Improving Security and Dependability- Current models restrict the ability to predict battery status, perform cell balancing, and optimize charging methods (electric/thermal and data-driven). Efficiencies need to be enhanced and costs reduced for batteries. Current variations impact State of Charge and State of Energy, while changes in capacity affect State of Health and Remaining Useful Life. Development of methods for accurately estimating battery conditions requires the implementation of multi-scale and co-estimation techniques that take into account different spatial and temporal scales. The computing time of BMS will decrease as a consequence.

6.2 Advanced Thermal Management- An effective BMS should employ smart techniques to predict the battery's condition and to resolve issues. Deep learning algorithms are hindered by problems with both time and training accuracy. Investigation on parameters and activity algorithms is necessary in order to accelerate the training procedure. Better management of battery temperature is necessary. Encouraging the use of sensor-less temperature sensing and electrochemical impedance spectroscopy can enhance accuracy and safety. More recent technology ought to be utilized in order to assess the indoor temperature as well. External battery thermal management technology involves cooling methods such as air/liquid and material.

6.3 Increasing the Capacity and Rapid Charging of Lithium-Ion batteries Numerous undisclosed elements impact the capacity of a LIB, such as vibrations, environmental factors, operating conditions, and technical variations. Predicting the outcome of all this accurately is not possible. New technologies are necessary to prolong the lifespan of LIBs. In order to enhance battery efficiency and prediction accuracy, it is essential to utilize innovative approaches for detecting abnormalities and incorporating a variety of driving techniques. The increase in electric vehicles leads to quick charging. A more advanced battery management system is necessary to avoid overcharging or overheating in rapidly charging batteries. The objective of BMS's charging system should be to utilize a charging strategy that is effective, secure, and relies on the best possible solutions.

6.4 Wireless BMS In order to create a universal and open-source BMS, it is necessary to develop adaptive techniques. Different manufacturers of BMS can collaborate to enhance efficiency by improving and advancing hardware and software. It will also increase the affordability of BMSs and meet future requirements by enabling the seamless incorporation of third-party features. Enhanced efficiency and changes in culture require a wireless BMS. By removing the excessive wiring in the current BMS, the cost, weight, and size of the BMS will be reduced. Due to the current wiring, any part that requires repair or replacement is more intricate or time-consuming. Wireless battery management systems offer two advantages: enhanced vehicle efficiency and lower operating expenses. 6.5

6.5 Repurposing and Reprocessing Research on battery reuse is important to save extra energy. These tactics must be both efficient and eco-friendly. It will also aid in conserving the Earth's finite stock of lithium-ion batteries. Used batteries still hold useful energy. If all 6831 cells in a Tesla Roadster's battery are not recycled, there will be a significant amount of waste. Government and non-governmental organizations should collaborate in developing new technologies to find the most cost-efficient and advantageous ways of extracting valuable energy and resources from old batteries. Different countries have varying regulations for managing the disposal of used LIBs. It is

[14] Zhou, W.; Zheng, Y.; Pan, Z.; Lu, Q. Review on the battery model and SOC estimation method. Processes 2021, 9, 1685. [15] Zhang, L.; Yang, Z.; Hu, F.; Feng, X.; Li, D.; Chen, Y. Reversible Al-Site Switching and Consequent Memory Effect of Al-Doped $Li_4Ti_5O_{12}$ in Li-Ion Batteries. ACS Appl. Mater. Interfaces 2020, 12, 17415–17423.

necessary to establish rules that are universal and consistent to address this issue without causing harm to the environment and to improve the work of both scientists and industry.

6.6 Recommendations For Installing Strictly ollow the equipment ratings and labelling instructions. When replacing equipment, make sure the new one is suitable for use with the existing one. Having a third party verify is strongly recommended to guarantee product safety and prevent any errors made by the manufacturer or designer. Taking out the entire battery bank is always the best option compared to taking out only a few batteries. It is essential to maintain a safety logbook and conduct regular safety checks on the BMS to comply with future regulations or to make necessary modifications. Achieving flawlessness in hardware or software manipulation is essential for a secure BMS. The BMS will turn off and restart the load/charger if it notices unusual behaviour or readings.

Conclusions

Managing batteries is a crucial issue for the adoption of electric vehicles because of challenges related to battery lifespan, safety, cost, and temperature. Unlike other studies focusing on only one or two aspects of battery management, this research covers every aspect. This research examines different BMS configurations, characteristics, needs, and evaluations. Six key points were emphasized for the BMS, with a specific focus on techniques for balancing the charge of battery cells. BMS faces key hurdles like instant SOC and SOH estimation, ideal charging issues, heat control and runaway risks, and battery recycling and repurposing. This article proposes upcoming BMS trends like intelligent algorithms combining hybrids, universal BMS, improved prototype design, advanced predictive techniques, and BMS virtualization. This assessment indicates that despite using a range of appropriate algorithms and intricate approaches/models, BMSs encounter numerous challenges. The future EVs' battery management systems (BMS) need to perform a range of complex tasks instantly, in order to address the intricate characteristics of batteries, manage harsh environments, and fulfill the requirements of upcoming EVs. This study suggests that widespread adoption of EVs will be difficult unless existing problems are addressed and improved BMSs are developed. Vehicle engineers and EV producers will find the comprehensive discussion, analysis, and recommendations provided beneficial.