IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

BATTERY MANAGEMENT SYSTEM FOR ELECTRIC VEHICLES

Dr.V.Senthilkannan
Assistant Professor
Department of Mechanical Engineering
Paavai Engineering College,Namakkal,Tamilnadu,India

V.Sasidharan
Student
Mechanical department
Paavai Engineering College,Namakkal,Tamilnadu,India

S.Aakash
Student
Mechanical department
Paavai Engineering College,Namakkal,Tamilnadu,India

A.Anbarasan
Student
Mechanical department
Paavai Engineering College,Namakkal,Tamilnadu,India

ABSTRACT

Electric vehicles are set to be the dominant form of transportation in the near future and Lithium-based rechargeable battery packs have been widely adopted in them. Battery packs need to be constantly monitored and managed in order to maintain the safety, efficiency and reliability of the overall electric vehicle system. A battery management system consists of a battery fuel gauge, optimal charging algorithm, and cell/thermal balancing circuitry. It uses three non-invasive measurements from the battery, voltage, current and temperature, in order to estimate crucial states and parameters of the battery system, such as battery impedance, battery capacity, state of charge, state of health, power fade, and remaining useful life. These estimates are important for the proper functioning of optimal charging algorithms, charge and thermal balancing strategies, and battery safety mechanisms. Approach to robust battery management consists of accurate characterization, robust estimation of battery states and parameters, and optimal battery control strategies. This paper describes some recent approaches developed by the authors towards developing a robust battery management system.

Keywords:
battery management systems; battery fuel gauge; state of charge; state of health; power fade; capacity fade; robust estimation; predictive control

1. Introduction

The energy storage system (ESS) has become popular in many domains, such as electric vehicles (EV), renewable energy storage, micro/smart-grid applications, etc. Modern EV generations are a reliable substitute for an internal combustion engine (ICE). ICE-based trucks, ships, cargo, and aircraft consume one-third of fossil fuel. ICE and industries are the two primary sources and are the leading causes of the emission of carbon dioxide (CO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and nitrogen oxides (NO). These gases cause air pollution that is responsible for the greenhouse effect. In EV, the EES runs the EV motor and machines: air conditioner, navigation lights, etc. The EV is well known as a zero-carbon-emission vehicle, whence the release of SO_2, CO_2, NO, and CO have not been prominent during driving; it would be helpful to consider the environmental challenges and fossil fuel utilization.

Typically, EVs are fully/partially powered by storage energy (SE) in road-/highway-, rail-, air-, and sea-based vehicles. Nowadays, high-tech vehicles like private cars and city buses are currently being upgraded with ES. The cumulative EV market now stresses sustainable battery development, power-system involvement, tax revenue, cost, e-commerce accessibility, and the edge among the common choices for automation mobility. Recently, EVs have been progressively becoming popular in global markets such as China and Europe. Increasing the use of EVs instead of ICE vehicles can alleviate problems, such as global warming and greenhouse gases, that pose a threat to the environment. Numerous countries and companies are inspiring their people to use EVs in ways that are more prudent and convenient for EV implementation and management. EVs are considered an ESS transmitted in a smart/micro-grid system that uses synchronized charging energies to equipoise unbalanced solar power and wind generation. Currently, EV's ESS scales capacity from 17 kW to 200 kW, which is unbelievable because EVs can receive the electricity during the pick-up load period. It makes a fantastic way for the renewable energies' electrical structure to link to the grid, vehicle-to-grid (V2G), and grid-to-vehicle (G2V). In EVs, several energy storage devices (ESD) have been introduced, i.e., the super-capacitor (SC), battery, and fuel cell. Batteries are well-known electrochemical storage devices that supply electricity. In energy combustion, SC is an electromagnetic storage system wherein electrodes and electrolytes store static energy, and liquid hydrogen (H_2) is utilized in fuel cells. Autonomous ESD cells have 1.5 V to 5.5 V, which are connected in series, parallel, or series–parallel combinations in the ESD modules to accomplish the essential power of EV demands. ESD is the electrochemical store, and its chemical reaction happens during the discharging and charging time. The ESD output voltage and capacity rely upon the deterioration of the chemical reaction, which is caused by the shortening of the lifespan and cyclic life. The cell has been aligned askew with internal resistance, the thermal difference, and self-discharge in the ESD pack because of cell formation and overcharge/discharge. Different cells' voltage and power reduction in the ESD packs can cause an explosion during charging.

The storage energy powers EV accessories, the lighting system, the motor, and various operational mechanisms. The rechargeable ESDs, e.g., Li-ion battery (LIB), lead-acid battery, SCs, and nickel and zinc batteries, are used in EVs. The technological development of ESDs has caused an intense increase in ESD demand in the field of portable electrical apparatuses. However, lead-acid batteries have recently had an extensive worldwide market in solar ESSs, whereas the LIB has future demand in bulk ESS. Different types of ESDs are considered based on specific requirements in EVs. In EV systems, ESD specifications account for individual cell safety, especially energy storage capacity. The cell voltage of an ESD becomes imbalanced due to the under/overcharge, the cell's internal chemical properties, and temperature profile. The ESD lifetime can be increased by reducing the temperature hazards and balancing the cell voltage.

The battery management system (BMS), which is compulsory for an ESS, plays a vital role in EVs, as shown in Figure 1. The BMS ensures the ESD's lifelong service, safety, and balanced facility for EV driving. The BMS is an extensive structure containing inclusive mechanisms and performance assessment for numerous ESD types, cell monitoring, power, thermal management, charging/discharging procedures, health status, data acquirement, cell protection, and lifetime.

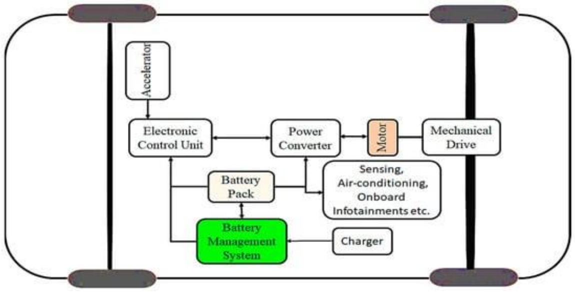


Figure 1. BMS operation inside the EV.

Cell voltage imbalance occurred during the charging/discharging time for internal electrochemical reactions in ESD. In BMS, cell voltage balancing is the leading work to improve cell life span and safety. Researchers and scientists are working on BMSs to develop highly efficient cell voltage/charge balancing systems to balance the cell voltage/charge, protect the cell from hazardous explosions, and improve its reliability.

2. Survey Methods

This survey aims to illustrate a straightforward discussion, critical analysis, and suggestions for BMSs. Therefore, the authors have gathered the most relevant and recent information containing key technologies, drawbacks, and research gaps. This survey determines the number of published articles based on four screening and assessment stages. The initial phase of the systematic literature review is the screening and assessment of BMSs in various databases, i.e., Google Scholar, ResearchGate, IEEE Xplore, ScienceDirect, and MDPI. Subsequently, we found 386 articles for analysis. Secondly, we searched our papers based on crucial work and selected 215 articles for analysis. In the third stage, we selected 155 articles to read the abstract, introductions, and conclusion. Fourthly, we selected 65 articles to read whole sections and content based on journal impact, citations, and the review process. Finally, we considered and established 91 articles to use as references and developed this review.

The result of the survey is divided into four steps. Firstly, the EV-related battery is discussed. Secondly, various aspects of BMSs have been clarified. Thirdly, the issues and challenges of the BMS for EV systems have been investigated and discussed. Finally, future directions for further improvement of BMSs have been presented. The survey structure has been completed in two steps that are as shown in Figure 2.

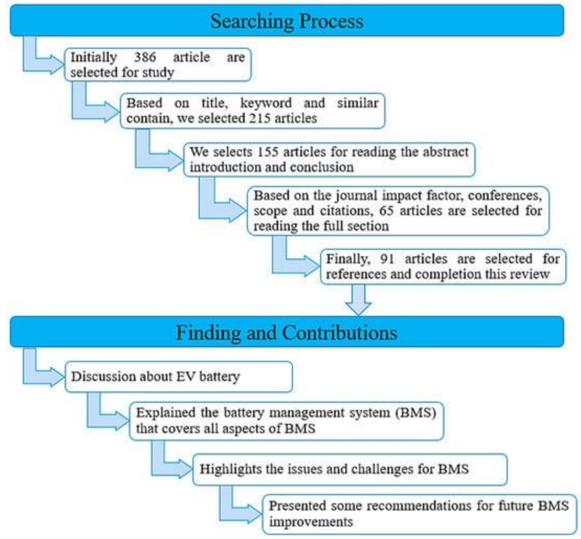


Figure 2. Schematic design of the reviewing methodology.

3. Battery

A battery is an electrochemical ESD that delivers electric power. EVs employ secondary electrochemical batteries, which have greater power and energy. The technological advancement of batteries has significantly impacted the automation/EV sector. Researchers have been consistently working on the EV battery system to provide greater specific power and energy density batteries. Batteries with high specific energy and power density, extended life term, and high-temperature tolerance are utilized in EVs. In EVs, various rechargeable batteries are used, such as nickel-based batteries, LIBs, and sodium–sulfur-based batteries. LIBs have 0.3 MJ/kg energy density (more than 100 times less than gasoline, which has 48 MJ/kg energy density), but it is a suitable alternative for EV application. At present, LIBs are the most applied EV system.

LIBs are usually utilized in consumer devices, EVs, and grid storage. Positive electrode materials include lithium metal oxide ($LiCoO_2$, $LiNiO_2$, $LiMn_2O_4$) and lithium iron phosphate ($LiFePO_4$). Graphite is often used in negative electrodes. The electrolyte is a non-aqueous lithium salt. Electrical insulation uses a LiPF6 separator. LB offers high energy density, specific energy, long lifespan, high cycle efficiency, quick reaction time, and low individual discharge rates . Li-ion batteries' high price and safety hazards when overcharged restrict their usage in the power sector.

3.Battery Management System

It is considered as the brain of the batteries that are delivering power to the electric engine, the good understanding of the parameters that the BMS is monitoring as well as its working process and components seems to be an inevitable step in our research. 5.1 OVERVIEW OF BMS: The storage module in some battery-powered applications is equipped with a power management and distribution system known as a Battery Management System "BMS." The system is linked to other on-board modules and controls charging and discharging in real time to improve 27 performance according to requirements while lowering the danger of battery degradation. This regulation prevents the battery from being overcharged or discharged. The BMS is in charge of ensuring that numerous duties such as state-of-charge determination, electrical management, and safety management are completed during the mission.

4. Electric Vehicle Basics

Electric vehicles (EVs) use electricity as their primary fuel or to improve the efficiency of conventional vehicle designs. EVs include all-electric vehicles, also referred to as battery electric vehicles (BEVs), and plug-in hybrid electric vehicles (PHEVs). In colloquial references, these vehicles are called electric cars, or simply EVs, even though some of these vehicles still use liquid fuels in conjunction with electricity. EVs are known for providing instant torque and a quiet driver experience. Other types of electric-drive vehicles not covered here include hybrid electric vehicles, which are powered by a conventional engine and an electric motor that uses energy stored in a battery that is charged by regenerative braking, not by plugging in, and fuel cell electric vehicles, which use a propulsion system similar to electric vehicles, where energy stored as hydrogen is converted to electricity by the fuel cell.

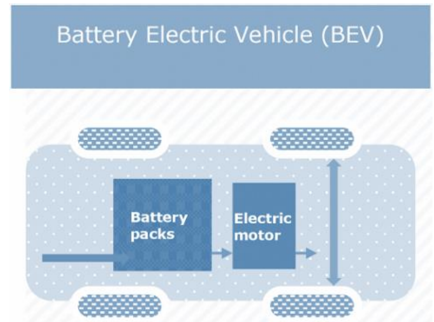
5.Types of Electric Vehicles

There are four types of electric vehicles available:

- Battery Electric Vehicle (BEV)
- Hybrid Electric Vehicle (HEV)
- Plug-in Hybrid Electric Vehicle (PHEV)
- Fuel Cell Electric Vehicle (FCEV)

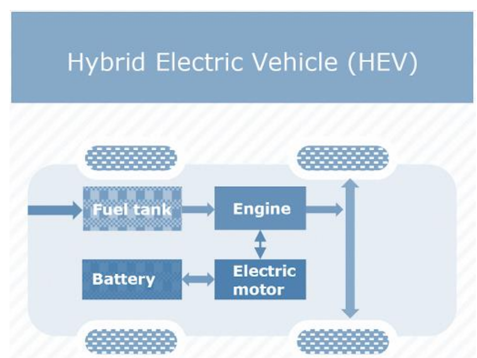
Battery Electric Vehicles (BEVs)

BEVs are also known as All-Electric Vehicles (AEV). Electric Vehicles using BEV technology run entirely on a battery-powered electric drivetrain. The electricity used to drive the vehicle is stored in a large battery pack which can be charged by plugging into the electricity grid. The charged battery pack then provides power to one or more electric motors to run the electric car.



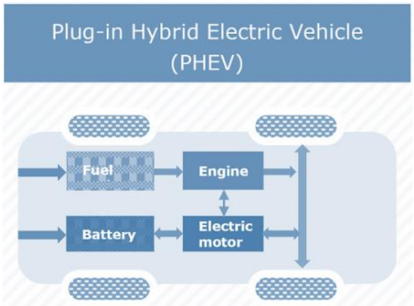
Hybrid Electric Vehicle (HEV):

HEVs are also known as series hybrid or parallel hybrid. HEVs have both engine and electric motor. The engine gets energy from fuel, and the motor gets electricity from batteries. The transmission is rotated simultaneously by both engine and electric motor. This then drives the wheels.



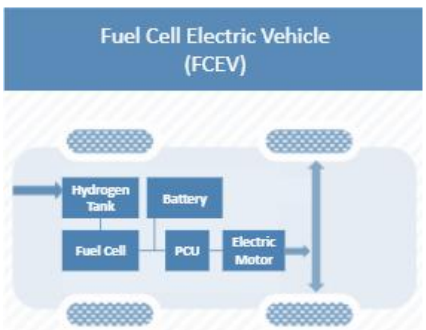
Plug-in Hybrid Electric Vehicle (PHEV):

The PHEVs are also known as series hybrids. They have both engine and a motor. You can choose among the fuels, conventional fuel (such as petrol) or alternative fuel (such as bio-diesel). It can also be powered by a rechargeable battery pack.



Fuel Cell Electric Vehicle(FCEV):

FCEVs are also known as Zero-Emission Vehicles. They employ 'fuel cell technology' to generate the electricity required to run the vehicle. The chemical energy of the fuel is converted directly into electric energy.



6. Issues and Challenges

LIBs have several features: high capacity, high power and energy density, high-temperature tolerance and cyclic life, long duty cycle, fast charging, and less effective memory. However, there are some issues, so it is required to indicate appropriate solutions for safety excitabilities, recycling and environmental impacts, custom and expansive characteristics, and the discharging- and charging-period memory effect for a wide range of sequential uses. These issues are also applicable to other electrochemical batteries for EV applications. The following are summaries of the main problems.

6.1. Real-Time SOC and SOH Estimation

SOC estimation is challenging due to the highly non-linear properties of EVs. However, it has flaws like early SOC faults, current measurement and integration faults, and battery capacity uncertainties. Furthermore, the battery needs to rest; measuring open-circuit voltage is impossible in real-time. There is a technique for estimating parameter errors, voltage and current measurement errors, aging, and temperature. It takes longer and costs more money to use electrochemical impedance spectroscopy (EIS). Various SOC and SOH estimation methods (**figure 3**) determine EV batteries' SOC and SOH. However, real-time determining the SOC in practical situations is difficult with the present methods. A low-cost BMS with little memory but high speed is the most challenging to estimate SOC. Current methods for real-time SOH estimation do not include minority battery health. Presently, model-based techniques have some drawbacks and cannot correctly predict health states . Different training and machine learning methodologies are also problematic when using data-driven approaches. As a result, the owner has two choices: replace the battery before it completely fails, increase the risk of a financial burden and environmental waste for the owner, or wait for the storm to fall.

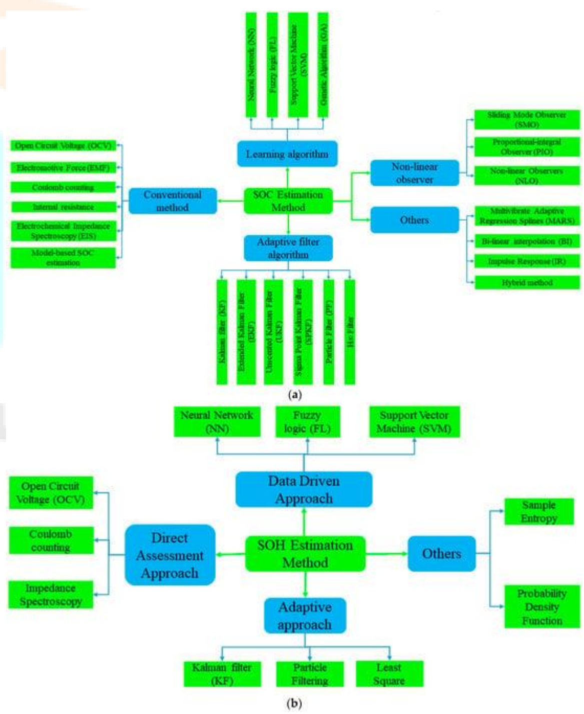


Figure 3. Taxonomy of SOC and SOH estimation method, (**a**) SOC estimation; (**b**) SOH estimation.

6.2. Optimal Charging Problem and Characterization

The current charging technique takes a long time to charge an EV's batteries with a battery pack, which is less efficient and less safe. The CC trickle is the most common technique for charging methods. However, as it uses low currents, charging takes a longer time. Increasing the charging current reduces charging time but raises the OCV of streamers above the safe threshold and generates heat. There are significant drawbacks to traditional battery charging methods. Therefore, balancing the charging efficiency, heat, battery lifespan, and degradation is challenging. There are several concerns with the real-time estimations of SOC and SOH in a BMS since they are time-demanding and inaccurate. Simple OCV–SOC models for real-time SOC assessments are less accurate and accumulate errors from other estimated parameters. These OCV models encompass the predicted SOC range based on battery usage and the entire SOC range, mainly obtained with a complete charge/discharge profile. It is challenging to characterize SOH in real time.

6.3. 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 computational complexity highly depend on test data and training procedures. It has resulted in several clever techniques/algorithms.

6.4. Battery Charger and Discharging Issue

Another problem for BMS is the lack of universal battery chargers. Custom battery chargers tend to be more compact and intended for domestic use, leading to increased electrical clutter and environmental waste. As a result of the wide variety of batteries in use, battery charger designers must handle this issue. Working with damaged or old batteries necessitates using safe–discharge batteries, which can be dangerous. Batteries in brine produce hydrogen and oxygen gases that must be vented to avoid detonation. Using resistors to release batteries requires a low current to prevent overheating.

7. Conclusions

Battery management is a critical concern for EV adoption due to battery life cycle, safety, cost, and temperature difficulties. In contrast to other works that analyze only one or two aspects of battery management, this work examines all facets. This study discusses various BMS topologies, features/functions, requirements, and comparisons. For the BMS, six points were highlighted, especially focused on battery cell charge balancing techniques. BMS's main challenges are real-time SOC and SOH estimation, optimal charging problems, thermal management and runaway, and battery recycling and reuse. This paper suggests future BMS trends such as hybridized intelligent algorithms, universal BMS, efficient prototype design, enhanced predictive methods, and BMS virtualization. This review shows that BMSs still face several obstacles, even when applying various suitable algorithms and complex approaches/models. Future EVs' BMS must execute numerous advanced activities in real time to handle the complicated nature of batteries, cope with severe conditions, and meet future EVs' needs. This research shows that EV adoption will be challenging unless current issues are solved and better BMSs are built. A complete discussion, analysis, and suggestions are provided, which will be helpful to vehicle engineers and EV producers.

References:

1. Hasan, M.K.; Mahmud, M.; Habib, A.A.; Motakabber, S.; Islam, S. Review of electric vehicle energy storage and management system: Standards, issues, and challenges. *J. Energy Storage* **2021**, *41*, 102940. [**Google Scholar**] [**CrossRef**]
2. 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. [**Google Scholar**] [**CrossRef**]
3. 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. [**Google Scholar**] [**CrossRef**]
4. 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. [**Google Scholar**] [**CrossRef**]

5. Ravi, S.S.; Aziz, M. Utilization of Electric Vehicles for Vehicle-to-Grid Services: Progress and Perspectives. *Energies* **2022**, *15*, 589. [**Google Scholar**] [**CrossRef**]
6. Ouramdane, O.; Elbouchikhi, E.; Amirat, Y.; Gooya, E.S. Optimal Sizing and Energy Management of Microgrids with Vehicle-to-Grid Technology: A Critical Review and Future Trends. *Energies* **2021**, *14*, 4166. [**Google Scholar**] [**CrossRef**]
7. Sehil, K.; Alamri, B.; Alqarni, M.; Sallama, A.; Darwish, M. Empirical Analysis of High Voltage Battery Pack Cells for Electric Racing Vehicles. *Energies* **2021**, *14*, 1556. [**Google Scholar**] [**CrossRef**]
8. 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. [**Google Scholar**] [**CrossRef**]
9. Iqbal, M.Z.; Aziz, U. Supercapattery: Merging of battery-supercapacitor electrodes for hybrid energy storage devices. *J. Energy Storage* **2022**, *46*, 103823. [**Google Scholar**] [**CrossRef**]
10. Olabi, A.; Wilberforce, T.; Sayed, E.T.; Abo-Khalil, A.G.; Maghrabie, H.M.; Elsaid, K.; Abdelkareem, M.A. Battery energy storage systems and SWOT (strengths, weakness, opportunities, and threats) analysis of batteries in power transmission. *Energy* **2022**, *254*, 123987. [**Google Scholar**] [**CrossRef**]