Issues and Challenges for Intelligent Battery Management System in Electric Vehicles

Ms. Snehal Shinde[1], Dr. Nikita Kulkarni[2]

Abstract: Background**:** Electric Vehicle is an emerging sector in the world. In electric vehicles, the battery and battery management system (BMS) are the most essential components. Performance of electric vehicles highly depends on battery management system operations. Issues and challenges in BMS can degrade vehicle's performance. **Methods:** We selected about 51 articles having higher relevance factors from the Scopus database. We analyzed 25 articles to study challenges in BMS in detail. In this article, we have addressed the issues and challenges which may affect electric vehicle efficiency. **Findings:** The challenges like real time state estimation, data security, temperature management, charging-discharging of battery, prediction of battery life, power source availability, disposal issues, etc are most common. These challenges can be considered for enhancing electric vehicle performance. **Conclusion:** Analysis of issues and challenges in BMS is provided in this paper.

1. INTRODUCTION

Nowadays, the biggest issue the world is facing is Global Warming. The conventional (fossil fuelled) vehicles are the biggest contributors to the pollution. Electric vehicles are proven to be the best option for conventional vehicles as they do not make use of fossil fuels. Instead, it uses the li-ion battery. Therefore, Electric vehicle usage is rising significantly. Electric vehicles in world are rapidly increasing [1]. There are some problems associated with electric vehicles such as battery cost, poor charging infrastructure, environmental factors, temperature issues, etc. These limitations reduce the efficiency of electric vehicles [2].

As technology grows, the ways of charging electric vehicles have been revolutionized. Madhu B.R. et al. offers a solution for fuelling electric vehicle. The system combines the benefits of solar and green energy to implement a solar-powered charging station [3].

Batteries are a crucial element of electric vehicles. Life of vehicle mostly depends on its battery's life. Longer the battery runs, the longer the electric vehicle works. But the limitations to the battery and BMS may degrade the EV performance [5,7].

Batteries possess some advantages like increased energy density, minimal environmental effect, long lifespan and power electric vehicles. The development of battery technology will determine how widely EVs are adopted

[6]. There are initiatives underway to improve energy storage efficiency, shorten charging times, and cut expenses. Because of their advantageous qualities, currently electric vehicles predominantly utilize lithium-ion battery technology; nevertheless, researchers are also looking at alternative battery chemistries [8].

Battery management systems continuously monitor the battery unit of electric vehicles. Apart from monitoring it also performs the operations such as estimation of states, protection to battery, balancing of battery cells, providing status to external devices. BMS keeps the battery of electric vehicles within a safe environment. Therefore, BMS should work efficiently by overcoming the issues and challenges it is facing [12]-[23].

Battery management system keeps an eye on voltage, temperature and current of battery. These parameters are then used for state estimation i.e SoC and SoH. There are numerous ways to estimate these values. It includes use of Virtual Sensor, Extended Kalman Filter, Machine Learning Algorithms, Deep Learning, etc. Battery lifespan can also be predicted using machine learning algorithms [25]-[34].

2. METHOD

The review process is done in-depth. The process of review is described in this section.

1. Selection of Keywords: According to selected topic i.e. "Challenges in Battery Management System", the keywords such as "Challenges", "Battery Management System", "Electric Vehicles" were selected for the search process.

[1]*Department of Computer Engineering, KJ College of Engineering & Management Research, Savitribai Phule Pune University, Pune, India*
[2]*Department of Computer Engineering, KJ College of Engineering & Management Research, Savitribai Phule Pune University, Pune, India*
Corresponding Author: Ms. Snehal Shinde
Email: snehalshinde624@gmail.com

2. Search Articles: By using selected keywords i.e. "Challenges", "Battery Management System", "Electric Vehicles", we started searching for articles to collect relevant literature data. Mostly we accessed articles from the Scopus Database. At an initial stage, we selected 150 articles for study. By considering the relevance factor, 52 articles finally filtered for detailed analysis.

3. Inclusion and Exclusion Criteria:

We applied inclusion criteria as:

- The article should be written in the English language.

- The article must have been published between 2020-24.

- The article must focus on a selected topic.

The exclusion criteria applied on selected articles is as follows:

- The article is written in another language.

- The article was published before 2020.

- The article focused on a topic which is out of scope.

4. Content Analysis: We analyzed the Abstract, Introduction and Conclusion sections gathered from selected articles to find out the relevance factor. Total 52 articles with a high relevance factor were selected for conducting a review to find out challenges in the Battery Management System.

5. Findings: From selected articles, we discovered the information about battery management systems and discussed issues and challenges in electric vehicles. We tried to uncover the research gaps of different articles.

The battery management system has multiple advanced features such as battery monitoring, battery cell balancing, estimating states of battery, controlling charging and discharging conditions, etc. BMS also controls the battery and hence improves performance of electric vehicles. However, it also comes with some challenges and issues. These challenges must be addressed and appropriate solutions needs to be implemented.

3.1. Issues and Challenges:

1. Real-Time SOC and SOH estimate: Because of the extremely non-linear characteristics of EVs, SOC estimate is difficult [34]. It does, however, have several shortcomings, such as battery capacity uncertainties, early SOC problems, and current measurement and integration errors. Moreover, the battery must be rested; real-time open-circuit voltage measurement is not feasible. It is more expensive and takes longer. The SOC and SOH of EV batteries are estimated using a variety of techniques [25]. However, using the current techniques

to determine the SOC in real-time in realistic scenarios is challenging.

2.Battery Models: Physical (equivalent, electrochemical) and data-driven (hybrid) methods are commonly used to characterize BMS batteries [4,37]. The requirement for exact conditions makes it impractical to conduct testing in varied environments [39]. It has produced a number of ingenious methods or algorithms.

3. Data Security: The quantity and variety of data that is available determines how accurate the sophisticated algorithms in battery models are. However, collecting a sizable variety of data takes time, which raises the danger of over-fitting and increases computer complexity.

4. Thermal management: Especially when it comes to monitoring temperatures inside, a smart BMS is dependent on precise, reasonably priced temperature sensors with a broad temperature range. Increasing the frequency of its charges and discharges helps to facilitate its irreversible chemical process. Possible side effects include overcharging, lithium plating, heat buildup, short circuiting, and explosion [36].

5. Problems with RUL Prediction: Insufficient modeling, noise in the system, and decreased sensor fidelity are few of the factors that make it challenging to forecast battery life using a battery management system. This approach is limited to limited number of battery models due to the numerous unknowns surrounding battery life prediction using aging mechanisms. While computational challenges impede attempts to apply hybrid approaches, inconsistency in health estimator makes it challenging to reliably predict battery life using data-driven approches [27].

6. Battery Charger and Discharging: The lack of common chargers presents another issue for electric vehicles [21]. Due to smaller size of custom chargers of battery, they are suitable for home usage. It results in electrical wastage production in environment. Currently a large range of batteries are in use. Safe-discharge batteries must be used when working with old or damaged batteries, which might be risky. In order to prevent explosion, hydrogen and oxygen gasses produced by batteries in brine must be released. In order to avoid overheating when releasing batteries via resistors, a low current is needed.

7. Safe and Effective Functioning: Batteries that are undercharged possess reduced lifespan. Because of internal and environmental elements that are always changing, batteries do not have a safe functioning range. This could lead to serious issues with the stability and dependability of the cell. Furthermore, a variety of

factors affect the electrochemical characteristics of batteries, making it challenging to maintain a proficient operating condition, particularly for BMS peripheral control units.

8. Reusing and Recycling Batteries: Battery recycling is another issue that needs to be addressed. For handling battery wastage, the system to collect and recycle them is needed. Furthermore, it decreases environmental issues. No clear process exists that has the least detrimental effects on the environment, though. Reusing batteries presents another issue for BMSs. The use and exposure of batteries to various environmental conditions over time results in alterations to their electrochemical characteristics. We can't assume aged battery as new battery. Batteries also contain metal including cobalt, aluminum, and copper. It would be beneficial if we could use these batteries once more due to the faster extraction of the metals used in batteries and an increase in their pricing. These days, ESS and applications are utilized globally for mass retired batteries. For battery safety during the second life cycle, the BMS is necessary [35].

9. Chargers Interaction: For proper operation, the BMS needs to establish connections with the internal parts of the car, the charger, and external gadgets. Different busses are utilizes to communicate internally. By communicating, charger receives data about the battery's current condition and past usage though buses. However, designing a consistent connection with the charger is difficult because there are so many different battery kinds and manufacturers.

10. Self-Discharge and Rate of Charging and Discharging: Errors in SOC estimation might arise from battery self-discharge. Self-discharge can be caused by temperature changes, cycle times, storage times, and impacts of the diffusion process. The charging and discharging rates affect the SOC evaluation. To maintain the battery within safe condition is the most crucial.
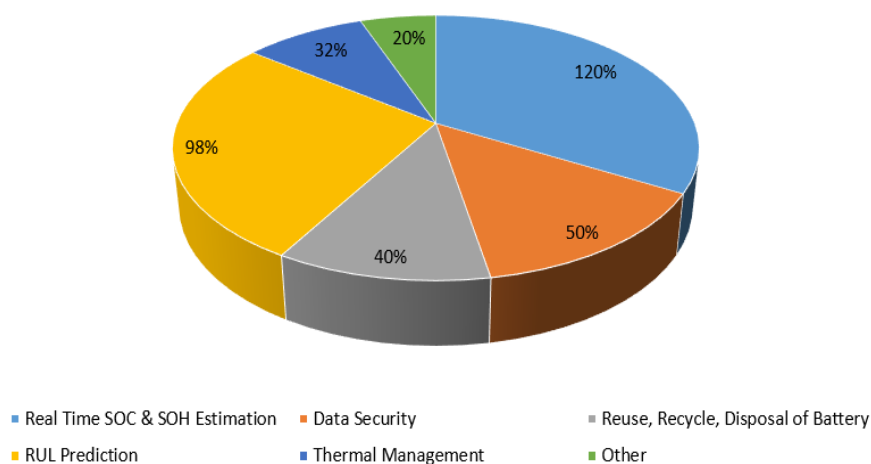
11. Source and Usage of Power: Battery is the only source of power in electric vehicles. It is most challenging to design BMS which protects the battery properly. An automobile's BMS uses energy when it runs, charges, or idles. For this reason, the BMS needs to use relatively little energy to keep the battery from running out when vehicle remains uncharged for longest time. It is common issue even with vehicles such as Tesla.

12. Problems with Battery Disposal: Some types of expended batteries are deemed hazardous waste, therefore they should be disposed carefully. If these batteries won't get disposed properly, it can cause explosions. It may raise safety concerns and environmental issues. The costs of cleanup are another consideration. The disposal of batteries is a multifaceted process that involves transportation, purification, disposal expenses, and regulatory considerations.

3. RESULTS AND DISCUSSION

The growth in battery management system's usage is rapidly increasing day by day. Multiple issues regarding BMS contribute to the performance of Electric Vehicles. The contribution we conclude for some major issues to performance degradation is represented in figure 1.

Figure 1. Effects of Issues in BMS on Performance of EV

In this study, we found that the performance of Electric Vehicle intensively gets affected by the issues and challenges it faces. The major issue arises in the real time calculation of battery charge level. It is not feasible to calculate battery charge status in real time by only considering the open circuit voltage. The type of battery used, thermal condition of battery also majorly affects the performance of EV. Electric vehicles have a lot of

data with them which makes them prone to cyber attacks. Data security, data privacy are major concerns which need to be considered while designing and implementing BMS. There exists some other challenges such as charging infrastructure, usage of power, charger interaction, etc. The smart and effective BMS can be developed by overcoming all those challenges which in turn increases the optimization of the battery and the vehicle.

4. CONCLUSION

In this article, a detailed analysis and evaluation of challenges encountered by battery management systems in electric vehicles is done. The key challenges such as real time state estimation, data security, temperature control, charging-discharging of battery, prediction of battery life, power source availability, disposal of battery have been discussed. The efficiency of the BMS can be enhanced by focusing more on these issues and challenges and finding out the solutions for those problems.

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BIOGRAPHIES OF AUTHORS

Ms. Snehal Shinde has received Bachelor of Engineering (BE) degree in computer science from the Savitribai Phule Pune University, Pune and currently pursuing Master of Engineering (ME) in Computer Science from the Savitribai Phule Pune University, Pune. She has participated in various Faculty Development Programs, Short Term Training Programs and Seminars. Her research interests include Internet of Things, Machine Learning and Electric Vehicles. She can be contacted at email: snehalshinde624@gmail.com

Dr. Nikita Kulkarni working as an Associate Professor and Head of Department of Computer Engineering in K J College of Engineering and Management Research, Pune. She has completed her bachelor, Master and Ph.D in Computer Engineering from Mumbai University. She has an experience of teaching in Computer Engineering and Information Technology courses over twenty years spanning across various institutes in Mumbai and Pune. She is a life-member of Indian Society for Technical Education (ISTE). She has 8 published patents, UK Design and Copyrights. She has published papers in various Scopus-indexed Journals, International journals and Conferences. She has also organized and participated in various Faculty Development Programs, STTP's, International Conferences, Seminars and workshops. She can be contacted at email: nikitakulkarni.kjcoemr@kjei.edu.in