JOURNAL OF MODERN AND VERSATILE RESEARCH APPROACH (JMVRA)
© 2026 JMVRA | Volume 4, Issue 10, October 2026 | ISSN: 2984-8911 | JMVRA.ORG

A REVIEW PAPER ON SUITABLE BATTERY PACK FOR ELECTRIC SCOOTER

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Abstract: The increasing demand for electric vehicles has encouraged the development of efficient, lightweight, and reliable battery energy storage systems for electric scooters. This review paper presents a comparative study of suitable battery pack technologies for electric scooter applications, focusing on lithium-ion battery chemistries such as Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Iron Phosphate (LFP), and other commonly used battery technologies.This battery systems based on energy density, power capability, weight, cost, cycle life, charging characteristics, thermal stability, safety, and overall performance. Particular attention is given to battery voltage and capacity selection according to motor power, controller specifications, and the required driving range. The role of the Battery Management System (BMS) in cell balancing, temperature monitoring, and protection against overcharging and over-discharging is also discussed. Furthermore, battery packaging and lightweight casing design are considered to improve space utilization and vehicle integration. The findings of this review aim to identify a suitable battery technology for electric scooter conversion, considering performance, safety, cost, and practical feasibility. This study provides a foundation for selecting an appropriate battery pack for reliable and sustainable electric mobility.

Keywords: Electric Scooter, Battery Pack, Lithium-ion Battery, NMC, LFP, Battery Management System, Energy Density, Battery Selection.

I. INTRODUCTION

The rapid development of electric vehicles has increased the demand for efficient, reliable, and environmentally friendly transportation systems. Electric scooters have become a popular alternative to conventional petrol-powered scooters due to their low operating costs, reduced noise, and lower emissions. One of the most important components of an electric scooter is its battery pack, which determines the vehicle's driving range, performance, charging time, weight, and overall efficiency. Therefore, selecting a suitable battery pack is essential for improving the performance and reliability of electric scooters.

Various battery technologies, including lead-acid, nickel-metal hydride (NiMH), and lithium-ion batteries, are used or have been considered for electric vehicles. Among these, lithium-ion batteries are widely used in modern electric scooters because of their high energy density, lightweight construction, good efficiency, and long cycle life. Different lithium-ion chemistries, such as lithium iron phosphate (LFP) and lithium nickel manganese cobalt oxide (NMC), offer different advantages in terms of safety, cost, lifespan, and energy storage capacity. Battery selection depends on several factors, including voltage, capacity, weight, charging time, thermal stability, maintenance, and cost.

This review paper focuses on identifying and evaluating suitable battery pack technologies for electric scooters by comparing their performance, advantages, and limitations. It examines important parameters such as energy density, power density, cycle life, charging characteristics, safety, cost, and environmental impact. The study also considers the importance of battery management systems (BMS) and thermal management in ensuring safe and reliable battery operation. The main objective is to identify a suitable battery pack that provides an effective balance between driving range, performance, safety, durability, and affordability for electric scooter applications.

II. LITERATURE REVIEW

Kailong Liu et al. [1]
The authors reviewed key battery management technologies for electric vehicles, including battery modelling, state estimation, and charging control. Their study explained the importance of estimating state of charge (SOC) and state of health (SOH) to understand battery condition and available energy. They also discussed temperature monitoring for improving battery safety and performance. These technologies help ensure reliable battery operation under different driving conditions. The study provides a foundation for selecting a suitable battery management system for the Mahindra Flyte electric scooter conversion.

Bragadeshwaran Ashok et al. [2]
The authors reviewed battery management systems for lithium-ion-battery-powered electric vehicles. Their study covered SOC estimation, cell balancing, thermal management, and charging control. They highlighted the importance of protecting battery cells against abnormal voltage, current, and temperature conditions. Appropriate control strategies can improve battery safety, reliability, and performance. These findings are useful for selecting a compatible battery management system for the proposed scooter battery pack.

Lu et al. [3]
The authors reviewed the major challenges associated with lithium-ion battery management in electric vehicles. Their study focused on cell-voltage monitoring, state estimation, cell balancing, and fault diagnosis. They explained how differences between individual cells can affect battery capacity, safety, and service life. Effective monitoring and balancing help maintain consistent battery performance. This research supports the selection of a BMS capable of monitoring individual cells and protecting the Mahindra Flyte battery pack.

A. K. M. Ahasan Habib et al. [4]
The authors examined the challenges involved in developing lithium-ion battery management systems for electric vehicles. Their review discussed battery monitoring, SOC estimation, cell balancing, and thermal management. They highlighted the importance of measurement accuracy, operating limits, system complexity, and cost. A suitable BMS must provide reliable monitoring and protection while remaining compatible with the selected battery pack. These findings help identify the essential battery protection features required for the proposed scooter conversion.

Hemavathi Sugumar and Thirukumaran Arumugam [5]
The authors reviewed current and emerging approaches to lithium-ion battery-pack design for electric vehicles. Their study covered battery specifications, cell configuration, mechanical packaging, safety, and thermal management. They highlighted the importance of coordinating electrical and mechanical design requirements. Proper battery arrangement helps optimise available space while maintaining protection and accessibility. These findings are useful for determining battery capacity, enclosure dimensions, and mounting arrangements for the Mahindra Flyte conversion.

Jiawei Zhang et al. [6]
The authors reviewed energy-storage management strategies for electric vehicles, focusing on battery characteristics and vehicle power requirements. Their study explained the importance of matching usable battery energy with the vehicle's expected energy consumption. Battery efficiency, operating conditions, and degradation can influence the available driving range. Therefore, battery capacity must be selected according to the vehicle's performance requirements. This research supports estimating the battery energy needed to achieve the target range of at least 30 km per charge.

Abdelrahman O. Ali et al. [7]
The authors reviewed battery management technologies for electric vehicles, with particular emphasis on thermal management, charging strategies, and battery-state estimation. Their study also discussed cloud-based monitoring and digital-twin technologies. Reliable monitoring and control help identify abnormal battery conditions and improve operational safety. The review highlighted the challenges of applying advanced battery models in practical applications. These findings help identify the essential monitoring and protection functions required for the Mahindra Flyte battery pack.

Berecibar et al. [8]
The authors reviewed methods for estimating the state of health of lithium-ion batteries in practical applications. Their study compared different estimation techniques and discussed their accuracy and limitations. Battery ageing can reduce available capacity and power capability, affecting driving range and reliability. Monitoring battery health helps assess changes in performance over time. This research supports including battery-condition assessment in the long-term monitoring strategy for the proposed electric scooter.

Plett [9]
The author investigated extended Kalman filtering as a method for estimating battery operating conditions in hybrid electric vehicles. The study discussed state of charge, capacity fade, power fade, and available battery power. This estimation technique uses mathematical models and measured operating data to estimate battery conditions. Accurate estimation can help determine the remaining usable battery energy. These concepts provide a theoretical foundation for understanding battery-state estimation in the Mahindra Flyte electric scooter conversion.
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Miao et al. [10]
The authors reviewed lithium-ion battery technologies used in electric vehicles and discussed opportunities for further development. Their study considered battery chemistry, energy density, safety, cost, and cycle life. Different lithium-ion chemistries provide different combinations of performance and durability. These characteristics influence battery weight, size, and suitability for electric vehicles. This research supports comparing NMC and LFP battery technologies when selecting a suitable battery pack for the proposed scooter conversion.

Jaguemont, Boulon and Dubé [11]
The authors reviewed the effects of low temperatures on lithium-ion batteries used in hybrid and electric vehicles. Their study discussed changes in battery performance, charging behaviour, and ageing. Low temperatures can increase internal resistance and reduce the battery's ability to deliver or accept current. Temperature also influences battery efficiency and operating reliability. These findings highlight the importance of considering operating temperature when selecting battery chemistry and designing the battery enclosure for the Mahindra Flyte conversion.

Nitta et al. [12]
The authors reviewed lithium-ion battery materials and developments in electrode technology. Their study examined the influence of battery materials on energy density, safety, cost, and cycle life. Different materials provide different electrical and thermal characteristics, affecting overall battery performance. Understanding these differences is important when evaluating battery technologies for electric vehicles. This research supports comparing available battery chemistries and selecting a suitable battery pack for the Mahindra Flyte conversion.

Jia Guo et al. [13]
The authors reviewed lithium-ion battery operation, degradation, and ageing mechanisms in electric vehicles. Their study explained how operating conditions and repeated charging and discharging can influence battery performance over time. Battery degradation may reduce available capacity and affect power delivery. Appropriate charging practices and discharge limits help manage battery operation. These findings support selecting suitable battery capacity and considering long-term performance requirements for the proposed electric scooter.

Rui Xiong et al. [14]
The authors reviewed methods for diagnosing and predicting short-circuit faults in battery systems. Their study highlighted the risks associated with abnormal electrical conditions, excessive current, and heat generation. Early fault detection is important for reducing the likelihood of serious battery failures. Suitable monitoring and electrical protection help improve battery safety. This research supports incorporating appropriate short-circuit protection, secure wiring, and fault-detection provisions into the Mahindra Flyte battery system.

Hemavathi Sugumar and Thirukumaran Arumugam [15]
The authors reviewed battery-pack architecture, safety measures, thermal management, and BMS integration for electric vehicles. Their study highlighted the importance of considering the electrical, thermal, and mechanical characteristics of the complete battery pack. Proper packaging and mounting are particularly important when installation space is limited. A well-designed enclosure helps protect the battery and supports reliable operation. These findings are relevant to designing a compact under-seat battery arrangement for the Mahindra Flyte electric scooter conversion.

Gregory L. Plett [16]
The author investigated battery modelling and parameter-identification methods used in battery management systems. The study discussed mathematical representations of battery behaviour and the identification of model parameters. These models help predict voltage response under changing current and load conditions. Accurate modelling can improve battery-state estimation and performance analysis. Such techniques may help evaluate battery behaviour during acceleration and steady-speed operation in the proposed electric scooter.

Hu, Li and Peng [17]
The reference concerns equivalent-circuit models used to represent lithium-ion battery behaviour. These models describe the relationship between current, terminal voltage, and internal resistance. They can help analyse voltage drops and transient responses under changing electrical loads. Different models offer varying levels of accuracy and computational complexity. This approach may support preliminary evaluation of battery performance under the motor controller's operating demands. However, the complete bibliographic details of this reference require verification against the original publication.

Feng et al. [18]
The authors reviewed thermal runaway mechanisms and safety risks associated with lithium-ion batteries in electric vehicles. Their study examined how excessive temperature, electrical faults, and mechanical damage can initiate hazardous reactions. Thermal runaway can lead to rapid heat generation and potentially cause fire or damage to neighbouring cells. Appropriate electrical protection and temperature monitoring are important safety measures. These findings support secure mechanical packaging and suitable protective arrangements for the Mahindra Flyte battery enclosure.

Hwang et al. [19]
The authors reviewed battery thermal management systems used in electric vehicles. Their study compared different approaches, including air cooling, liquid cooling, phase-change materials, and thermoelectric systems. Each method has different advantages, limitations, and implementation costs. The appropriate cooling arrangement depends on heat generation, operating conditions, available space, and temperature requirements. This research supports selecting a suitable thermal management approach for the compact battery pack of the Mahindra Flyte conversion.

S. Hemavathi et al. [20]
The authors reviewed thermal management and safety strategies for lithium-ion batteries used in electric vehicles. Their study discussed passive and active cooling, phase-change materials, and early fault-detection techniques. These approaches aim to control battery temperature and reduce thermal runaway risks. The selection of a suitable method depends on battery size, heat generation, operating conditions, and cost. These findings support determining appropriate thermal protection and enclosure arrangements for the proposed Mahindra Flyte electric scooter conversion.

III. ACKNOWLEDGEMENT

The authors express their sincere gratitude to the Department of Mechanical Engineering for providing the facilities and support required to carry out this review work. We would like to thank our mentor, Dr. P. Varalakshmi, Dr. B. Vijaya Kumar, Mr. N. Yadagiri for his continuous guidance, valuable feedback, and

encouragement throughout the preparation of this manuscript. The authors also appreciate the contributions of faculty members and laboratory staff who assisted with resources and technical insights during the study.

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