Chapter 9
A Comprehensive Review of State-of-the-Art Battery Energy Systems for Green Transportation

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ABSTRACT

The shift to environmentally friendly mobility is central to slowing down climate change, cutting dependence on fossil fuels, and curbing greenhouse gas emissions, thus speeding up the worldwide use of electric vehicles. Battery systems stand at the centre of this movement as they have direct impacts on EV performance, efficiency, and sustainability. This assessment examines the electrochemical processes, strengths, and weaknesses of different contemporary EV battery types, including lithium-ion, lead-acid, nickel-based, sodium-based, and those employed in hybrid, plug-in hybrid, and fuel cell vehicles. Lithium-ion batteries are notable for their ability to store a lot of energy per unit mass, have long lifetimes, and are efficient, yet they are the most widely used battery type in most EVs. Though cheaper, lead-acid and others are generally employed in HEVs and PHEVs because of lesser

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performance. A comparison highlights the role of each type in EV evolution. The significance of Battery Management Systems for safety, lifespan, and performance is also highlighted.

1. INTRODUCTION

The automotive industry has been a cornerstone of global transportation, enabling mobility, economic growth, and technological advancements (Hossain et al., 2022). Automobile manufacturers strongly dependent on fossil fuels have caused environmental problems that primarily stem from carbon emissions and climate-altering effects. The automotive industry has transitioned to electric vehicles (EVs) as sustainable options for people who no longer use conventional internal combustion engine (ICE) vehicles. Sustainability has driven increased investments from both developed and developing countries, who want to start making electric vehicles to replace non-renewable energy sources and deliver higher-demand, clean, and efficient transportation options (Ali & Naushad, 2022). Due to this emission, nowadays, renewable energy sources are preferred.

Renewable energy sources are naturally replenished and can be used continuously without depleting the Earth's resources. These include solar, wind, hydro, geothermal, and biomass energy, all of which provide cleaner alternatives to fossil fuels. Unlike conventional energy sources, renewables produce little to no greenhouse gas emissions, making them a key tool in addressing climate change and reducing air pollution (Renewables, 2021). In addition to environmental benefits, renewable energy also promotes energy security and economic development through job creation and local investments (Hillerbrand, 2018). As global demand for sustainable energy grows, renewable sources are becoming a vital part of the modern energy landscape.

At the core of EV technology lies the battery system, which directly influences vehicle performance, range, and longevity (Manzetti & Mariasiu, 2015). Lithium-ion batteries (LIBs) have emerged as the leading energy storage solution for EVs due to their high energy density, long cycle life, and efficiency. Other battery technologies, including lead-acid, nickel-metal hydride (NiMH), and sodium nickel chloride batteries, also play roles in specific applications, particularly in hybrid EVs (HEVs) and plug-in hybrid EVs (PHEVs). Equally important is the Battery Management System (BMS), which ensures battery safety, efficiency, and longevity. The BMS tracks essential battery elements, including temperature and voltage, and state of charge (SOC), to stop overcharging and deep discharging, and runaway thermals (UDHAYAKUMAR et al.). The BMS improves both battery life expectancy along vehicle reliability through optimized battery maintenance. Switches to smart BMS

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