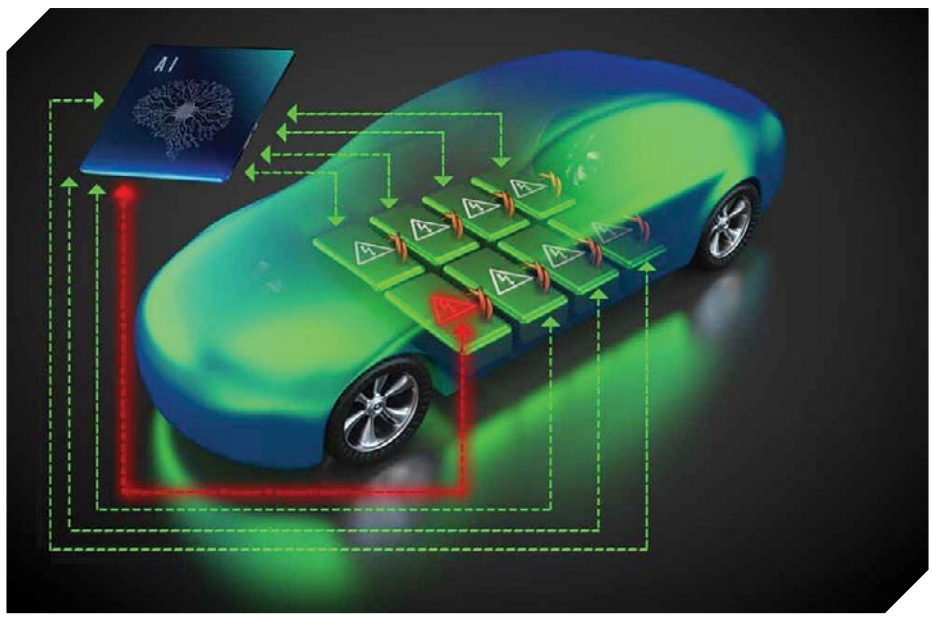
AI and IoT Powered Batteries: Advancements, Challenges, and Future Prospects

With rising EV adoption, AI and IoT are crucial for optimising battery performance and ensuring lasting energy efficiency, writes **Shrutika Godse**, Senior Consultant, Growth Advisory, Aranca.

The electric vehicle (EV) industry is undergoing significant transformation, driven by advancements in Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT). These technologies redefine EV battery management systems (BMS), optimise efficiency, enhance safety, and extend battery life. As India pushes towards its ambitious goal of achieving 30 per cent EV adoption by 2030, leveraging AI and IoT will be instrumental in ensuring sustainable and efficient battery solutions.



Growth of the EV market in India

The future of mobility is undeniably electric, and India is leading this transformative shift. As of 2024, the country's EV adoption has surpassed 5.6 million, marking a significant milestone, according to the Ministry of Road Transport and Highways. Notably, two-wheelers dominated the market, accounting for approximately 60 per cent of total EV sales (~3.36 million units), while four-wheelers contributed around 2 per cent (~99,848 units), reflecting the evolving landscape of India's electric mobility sector.

A key component of the EV ecosystem is battery technology. Lithium-ion battery packs dominate the two-wheeler segment due to their high energy density, while lead-acid batteries are more common in three-wheelers. Recently, nickel-metal hybrid batteries have started gaining traction in four-wheelers due to their balance between energy density and cost. Government incentives, growing awareness of environmental sustainability, and increasing demand for clean energy solutions are propelling the EV market forward. Leading companies such as Exide Industries, Amara Raja Batteries, and Tata Power are investing heavily in next-generation battery technologies to support this evolving industry.

The Evolution of the EV battery market

In India, EV battery capacities typically range from 15 kWh for compact electric cars to over 100 kWh for high-end electric SUVs, offering a real-world driving range of approximately 150 to 500 km on a single charge. The country's EV sector is poised for substantial expansion, with projections indicating that more than 150 GWh of lithium-ion battery cell capacity will be operational by 2030. Backed by strong government support, ICRA estimates that this development will be driven by investments exceeding ₹75,000 crore, reinforcing India's commitment to a sustainable electric mobility future. The cost of EV battery packs in India has declined by 85 per cent over the past decade. In 2023, prices reached INR 91.65 (USD 1.67) per kilowatt-hour (kWh), reflecting a 14 per cent drop from INR 162.29 (USD 1.93) per kWh in 2022.

India faces considerable challenges in establishing a strong domestic lithium-ion (Li-ion) cell manufacturing industry. Currently, over 80 per cent of essential EV battery components—including anodes, cathodes, and electrolytes—are imported, resulting in high production costs and significant dependence

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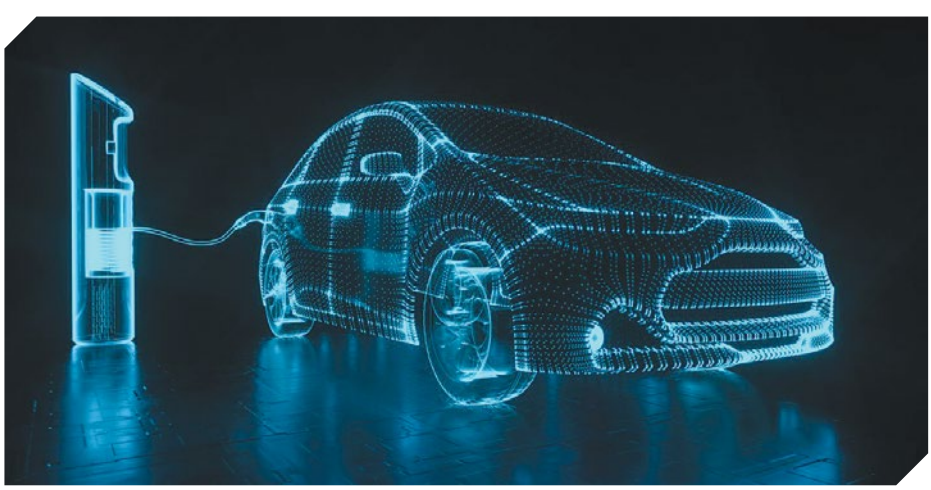
on countries like China. Although leading companies such as Tata and Exide Industries are investing in local manufacturing to strengthen domestic capabilities, reliance on imports remains a major constraint on industry growth. Additionally, India lacks a well-developed battery recycling infrastructure, further increasing production costs due to the need to import critical raw materials like lithium, cobalt, and nickel.

One of the key hurdles in this sector is the rapid pace of advancements in battery technologies. The emergence of solid-state and sodium-ion batteries presents a challenge for manufacturers who have heavily invested in lithium-ion technology. Despite this, lithium-ion batteries continue to dominate the global EV battery market due to their superior energy density, long lifespan, and lightweight properties.

However, safety concerns persist, particularly regarding the risk of thermal runaway—a phenomenon where battery temperature spikes unexpectedly, increasing the likelihood of failures, fires, or even explosions. Furthermore, heavy investments in lithium-ion infrastructure carry the risk of obsolescence as newer, more advanced battery technologies emerge. This uncertainty makes manufacturers and investors cautious, as they must balance short-term profitability with long-term sustainability.

While lithium-ion batteries have been the preferred choice for EVs, concerns over fire safety and limited raw material availability are prompting a shift towards alternatives such as nickel-metal and cobalt-based batteries. In March 2024, Ola Electric began mass production of NMV21700 cylindrical cell batteries at its Chennai Gigafactory for its two-wheelers.



AI-driven battery optimisation

AI is playing a crucial role in optimising battery performance. Advanced AI algorithms analyse vast datasets to improve battery integration, ensuring efficient energy utilisation, optimal weight distribution, and enhanced aerodynamics. These factors are essential for maximising the driving range and efficiency of EVs. AI is also enabling real-time monitoring of battery health, predicting failures before they occur, and enhancing overall safety.

AI-driven robotics and automation are revolutionising battery production. Automated systems perform repetitive manufacturing tasks with precision, reducing human error and ensuring consistent quality. AI-powered quality control mechanisms inspect components and battery packs during assembly, identifying defects early in the production process. Predictive analytics further help manufacturers anticipate supply chain disruptions, securing raw materials before shortages arise and maintaining seamless production cycles.

AI is becoming crucial in optimising EV charging infrastructure. AI-powered "smart charging" systems analyse battery status and suggest optimal charging times and locations to maximise range and battery longevity. These systems also help in balancing energy loads across the power grid, ensuring efficient energy distribution. Moreover, AI-driven battery management systems (BMS) continuously monitor battery health, regulating temperature and charging cycles to extend lifespan and minimise degradation.

Emerging Battery Technologies in the AI Era

Lithium Iron Phosphate (LFP) Batteries

LFP batteries are emerging as a