PERSPECTIVE

Future Development and Prospects of Key Technologies for Electric Vehicles: A Refined Perspective

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Abstract

Driven by multiple forces such as the rapid development of battery technology, environmental and energy issues, and government policies, the global automotive industry is accelerating its transition towards electric vehicles (EVs). However, there are still some challenges of key technologies for EVs, including battery energy density limitations, battery management technology, construction of charging infrastructure, etc. This perspective explores the future development and prospects of key technologies for EVs, which mainly focus on predicting future technologies of four main aspects: next-generation battery, fast charging and wireless charging, integration of autonomous and artificial intelligence, and integration of renewable and clean energy. By analyzing the latest research findings and related publications, we have conducted targeted analysis and a detailed description of the development of future technologies for EVs, which can provide an outlook on the future development trends of EVs.

Keywords: electric vehicles, EV technologies, future prospects.

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List of Abbreviations

AI	Artificial Intelligence
DWC	Dynamic Wireless Charging
EV	Electric Vehicle
LFP	Lithium Iron Phosphate
LIB	Lithium-Ion Battery
LSB	Lithium Sulfur Battery
LSTM	Long Short Term Memory
SIB	Sodium Ion Battery
SSB	Solid State Battery
V2G	Vehicle to Grid
V2X	Vehicle to Everything

1 Introduction

The development of electric vehicles (EVs) is an inevitable trend and has become an irreversible trend in the global automotive industry [1, 2]. This trend is driven by multiple forces such as technological progress, policy promotion, and market demand, and is reshaping the landscape of the energy, transportation, and technology industries. With the continuous advancement of battery technology, the range of EVs has been increasing year by year. A safer and more reliable battery solution effectively reduces safety hazards such as battery fires, giving consumers more confidence in the safety of EVs and promoting the rapid development of the new energy vehicle market.

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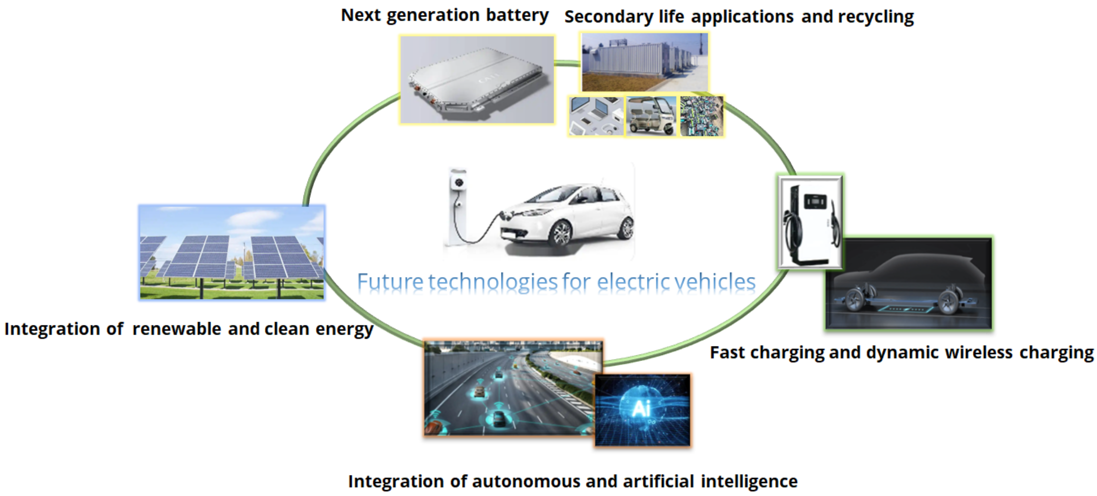

Figure 1. Future technologies for electric vehicles.

From the booming development of EVs in the deep innovation of intelligent driving technology, the intelligence and networking of EVs will further develop. There are still some key technological challenges for EVs, including battery energy density limitations, battery management technology, construction of charging infrastructure, etc. A perspective on the future development and prospects of key technologies for EVs is discussed as follows, with a focus on four aspects: next-generation battery, fast charging and wireless charging, integration of autonomous and artificial intelligence (AI), and integration of renewable and clean energy, as shown in Figure 1.

2 Power battery technology

The most critical determinant of EVs is the performance of the power battery [3, 4]. The current lithium-ion batteries (LIBs) have limitations in terms of energy density, charging speed, and lifespan. The progress and development of future power battery technology may include but are not limited to the next generation battery technology, such as solid state batteries (SSBs), lithium sulfur batteries (LSBs), and sodium ion batteries (SIBs), and battery secondary life applications and recycling technology.

2.1 Next generation battery technology

Solid state battery technology SSBs use solid materials instead of liquid electrolytes to provide higher energy density, estimated to be two or three times that of LIBs, and have higher safety and faster charging speed. Toyota and other vehicle companies aim to commercialize SSBs by 2030 [5]. The development prospects of SSB technology are very promising, which is crucial for further improving the driving range of electric vehicles.

Lithium sulfur and sodium ion battery technology LSBs are expected to achieve higher theoretical energy densities, estimated to reach 500 Wh/kg, but will be affected by polysulfide shuttle [6]. Although SIBs have lower energy density, they have cost advantages, better resource availability, and abundant reserves [7]. The core advantage of SIBs lies in their abundant resources and low cost. The abundance of sodium element in the Earth's crust is very high, a thousand times that of lithium, and it is evenly distributed globally without geographical limitations. Due to its low cost and high safety, SIBs are suitable for low-speed EVs and large-scale energy storage systems.

2.2 Battery secondary life applications and recycling technology

The secondary life application of retired batteries for EVs is very important. Retired batteries can continue to be used in new energy storage, low-speed EVs, electronic digital products, etc., which can further extend the service life of batteries [8]. As the final stage of the battery's life cycle, it involves dismantling and recycling, extracting valuable materials from the battery to manufacture new ones. When retired batteries no longer meet secondary life applications, the recycling of key materials such as lithium and cobalt is crucial for sustainable development. Emerging wet metallurgy and direct recycling methods can recover over 95% of battery materials [9].

3 Fast charging and wireless charging technology

3.1 Fast charging technology

The fast charging technology of power batteries is very important. This concerns the time cost for EV drivers, as no one wants to waste a lot of time waiting for the battery to charge. A high-power charging system can shorten the charging time of 80% capacity to less than 20 minutes [10]. Of course, the role of power devices in this regard cannot be ignored, such as new power electronic devices like SiC and GaN [11, 12]. In addition to high-power charging systems, new fast charging strategies are also a focus of research [13, 14].

3.2 Dynamic wireless charging technology

Dynamic wireless charging (DWC), also known as "charging while driving", involves installing charging coils on the road and receiving energy through a chassis receiver while the vehicle is in motion [15]. The development and implementation of this technology can significantly alleviate the range anxiety of EV drivers and make the user experience of EVs closer to traditional fuel vehicles. DWC is a technology that improves charging convenience, reduces physical plugging and unplugging operations, and promotes the development of autonomous driving and smart transportation [16, 17].

4 Integration of autonomous and artificial intelligence technology

4.1 Autonomous and connected vehicle technology

Autonomous vehicles, also known as self-driving automobiles, are a kind of intelligent vehicle that can be driverless through a computer system [18]. Autonomous vehicles rely on the cooperation of AI, visual computing, radar, monitoring devices, and a global positioning system (GPS), so that computers can automatically and safely operate motor vehicles without any human initiative. The integration of EVs and autonomous technology will redefine the mobility of EVs [19].

Autonomous vehicles cannot do without connecting technology, that is, the technology for information exchange and communication between vehicles and their surrounding environment, including other vehicles, pedestrians, road infrastructure, and networks. In other words, it is called the vehicle to everything (V2X). V2X enables EVs to interact with infrastructure such as traffic lights, charging stations, and other vehicles, optimizing energy use and reducing congestion [20], and is used to guide the optimal site selection and construction of infrastructure such as charging stations [21, 22].

4.2 Energy and battery management driven by artificial intelligence

AI, V2X, big data, and autonomous technology are profoundly changing the development of EVs, enhancing the performance, safety, and user experience. AI technology will play an important role in energy and battery management in EVs, such as energy allocation and optimization, battery state estimation, fault diagnosis, charging optimization, thermal management, etc. in the future. Machine learning algorithms are used to improve efficiency by predicting battery degradation and optimizing charging cycles [23]. And A transfer learning with long short term memory (LSTM) network is studied to implement state of health prediction of LIBs [24]. The development of AI technology is advancing rapidly, with powerful functions and applications in various industries. The development of various technologies in EVs also relies on the assistance of AI.

5 Integration of renewable and clean energy technology

The vehicle to Grid (V2G) technology refers to the technology of EVs delivering electricity to the grid, and its core idea is to use a large amount of stored energy from EVs as a buffer between the power grid and renewable and clean energy storage systems. The renewable energy like solar and wind power [25], and clean energy such as hydrogen energy, are crucial for combating climate change, reducing pollution, and ensuring long-term energy security. Solar integrated EVs and V2G systems allow for bidirectional energy flow and support grid stability [26]. And through AI technology, we can analyze the power grid load and select low-priced periods to charge EVs [27]. The shift to renewable and clean energy is essential for a sustainable future, and technological advancements and policy support are accelerating the transition.

6 Discussion and Conclusion

It should be pointed out that the development of technology cannot be separated from the support and drive of policies, markets, users, etc. Specifically, carbon emission standards and policies, business models, including battery leasing, integrated photovoltaic energy storage systems and charging stations, as well as user acceptance of EVs, directly affect the development direction and choices of future EV technologies in different countries. For example, in China, battery technology is currently dominated by lithium iron phosphate (LFP), with a focus on SSB research in the future. Currently, intelligent connected technology for autonomous vehicles with 5G+V2X is being developed; while in Japan, the focus is on developing SSBs and hydrogen fuel cells, and promoting the construction of hydrogen refueling stations through subsidies.

The future of EVs depends on breakthroughs in battery technology, charging technology, autonomous technology, and intelligent technology, etc. Despite ongoing challenges, interdisciplinary innovation and progress in fields such as electrochemistry, AI, and energy policy, will drive the new development of EVs.

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Conflicts of Interest

The author declares no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

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