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Application and Challenges of Battery Swapping Technology in the Development of New Energy Vehicle

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Abstract: With the rapid growth of the new energy vehicle market, the construction of battery swapping stations has become an effective solution to the problem of insufficient charging facilities. Battery swapping technology can improve energy replenishment efficiency, alleviate pressure on the power grid, reduce charging costs through overnight charging, and increase battery utilization and profitability. However, battery swapping technology faces issues such as standardization, high costs, technical and safety challenges, and low market acceptance. It is suggested to promote standardization, government policy support, technological innovation and safety enhancement, the construction of a widespread battery swapping network, as well as innovation in business models and market promotion to promote the development of battery swapping technology.

Keywords: New Energy Vehicle, Battery Swapping Technology, Charging Facilities

1. Introduction

With the rapid development of the automotive industry, environmental issues caused by exhaust emissions are becoming increasingly severe. Electric vehicles, powered by electricity, have the advantage of being clean and environmentally friendly, making them a promising solution to environmental pollution. Currently, China's new energy vehicle market is booming, with an estimated 21 million vehicles expected by 2025 and 65 million by 20306[1]. In the government work report of 2020, China clearly stated the need to "increase charging piles, battery swapping stations, and other facilities," indicating both the mismatch between the current development of charging pile industry and electric vehicle development, and the industry consensus on promoting battery swapping mode while constructing charging piles in the future. Therefore, in terms of development trends, the future of charging and battery swapping cannot evolve independently but rather complement each other. However, on one hand, there is still a shortage of charging and battery swapping facilities, despite ongoing expansion. On the other hand, existing energy supply facilities suffer from low efficiency and poor customer perception due to the randomness and uncertainty of electric vehicle energy supply demands in time and space[2]. The increasing energy supply demands of electric vehicle users, coupled with limited charging and battery swapping facilities and low facility utilization rates, have become one of the main constraints on the development of the electric vehicle industry. Therefore, effectively improving the utilization rate of energy supply facilities and thereby enhancing the energy

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supply efficiency of electric vehicles are crucial for improving customer perception and industry development[3].

2. Overview of Battery Swapping Station Technology and Current Applications at Home and Abroad

2.1. Overview of Battery Swapping Station Technology

The electric vehicle battery swapping model refers to the centralized storage, charging, and unified distribution of a large number of batteries through centralized charging stations, and providing battery replacement services for electric vehicles at battery distribution stations; or through battery swapping stations integrating battery charging, logistics, deployment, and swapping services.

There are mainly two types of battery swapping models: centralized charging model and charging-swapping model. The centralized charging model refers to the centralized storage, charging, and unified distribution of a large number of batteries through centralized charging stations, and providing battery replacement services for electric vehicles at battery distribution stations. The charging-swapping model refers to the battery swapping station as the carrier, where the station simultaneously functions for both battery replacement and battery charging. The station includes power supply systems, charging systems, battery swapping systems, monitoring systems, battery detection and maintenance management sections, etc[4].

2.2. Current Applications of Battery Swapping Station Technology Internationally and Domestically

Battery swapping technology essentially involves using equipment to replace car batteries. However, this technology is still not mature enough, with high costs leading to low coverage rates. Additionally, the lack of standardized battery specifications results in poor universality of battery swapping stations. Moreover, car owners' acceptance and recognition of the battery swapping model are lower compared to other charging methods.

Currently, there are five main companies in China operating in the battery swapping sector. NIO is considered the leader in this field, having built 900 battery swapping stations covering 57 cities. However, its products are only compatible with its own vehicle models, resulting in poor compatibility. Aulton New Energy, another player in the market, boasts high efficiency in battery swapping and has built 610 stations covering 36 cities[5]. Beijing Blue Valley, a subsidiary of BAIC Group, has steadily promoted its products in the market and has constructed 277 swapping stations in 21 cities. Bertank Technology holds a smaller market share, with 55 swapping stations covering 14 cities. Lexing Battery Exchange, a cooperation between CATL and Aiways, is a newcomer in the market and has just begun its battery swapping business with four stations in Xiamen.

Regionally, battery swapping stations are more prevalent in economically developed cities. The economic level of each city is directly related to the number of electric vehicles owned, with some cities implementing policies to promote new energy vehicles by restricting the registration of vehicles that do not meet the latest emission standards and imposing restrictions on traditional fuel vehicles within the city. These measures and policies encourage people to purchase electric vehicles, thereby increasing the sales of electric vehicles and promoting the construction of battery swapping stations[6].

By the end of 2021, there were a total of 1,192 battery swapping stations in China, double the number compared to 2020. It is expected that by 2025, the number of battery swapping stations in China will exceed 20,000, indicating that the construction of battery swapping stations nationwide is in a period of rapid development[7].

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2.3. Subsidy Policies for Battery Swapping Stations

The Chongqing Municipal Finance Bureau issued the "Notice on the Financial Subsidy Policy for Chongqing's Charging and Swapping Infrastructure in 2023 (Draft for Soliciting Opinions)." The proposal suggests that for battery swapping stations providing shared swapping services and compatible with multiple brands and models of vehicles, a one-time construction subsidy of 350 yuan per kilowatt will be provided based on the rated charging power of the battery swapping equipment. The maximum subsidy for battery swapping stations serving taxi, online ride-hailing, postal delivery, and urban logistics operations will not exceed 500,000 yuan per station, while for stations serving urban sanitation, construction waste transportation, port operations, and trunk logistics, the maximum subsidy will not exceed 800,000 yuan per station. For the construction and operation of DC charging piles newly built and put into operation in the central urban area and outside the central urban area, a one-time construction subsidy of 150 yuan per kilowatt and 200 yuan per kilowatt, respectively, will be provided. For newly built and put into operation DC charging piles in service areas along the highways within the city, as well as 3A-grade or higher scenic spots, a one-time construction subsidy of 300 yuan per kilowatt will be provided. For newly built and put into operation high-power charging piles with a single pile power of not less than 350 kilowatts within the city, a one-time construction subsidy of 350 yuan per kilowatt will be provided[8].

The "Implementation Rules for the Construction and Operation Awards and Subsidies for Electric Vehicle Charging and Swapping Facilities in Beijing in 2022" propose that the operation awards for swapping facilities are divided into daily rewards and annual rewards. The daily reward standard is 0.2 yuan per kilowatt-hour, and the annual reward standard is divided into four levels based on the assessment results of charging and swapping stations, specifically 106 yuan per kilowatt-year (Grade A), 90 yuan per kilowatt-year (Grade B), 74 yuan per kilowatt-year (Grade C), and 0 (Grade D)[9].

3. Advantages and Challenges of Battery Swapping Stations Technology

3.1. Advantages of Battery Swapping Stations Technology

Under the charging mode, each parking space needs to be equipped with a charging pile, and the additional demand for energy replenishment is met by building new charging piles. At the same time, it is difficult to control the duration of vehicle occupation of parking spaces, resulting in low utilization rates of parking spaces and the potential for idle charging piles. Battery swapping stations have higher efficiency, allowing vehicles to complete battery swaps in a short time, achieving "swap and go".

In the fast charging mode, the battery charging time remains relatively long, with half an hour required to reach 80% battery capacity. The overall efficiency of the battery swapping mode is higher, with shorter battery swapping times, significantly reducing the time required for energy replenishment, with an average swapping time of less than 5 minutes. In the battery swapping mode, swapping stations can efficiently manage and operate battery assets, thereby better exploring the value of power batteries in aspects such as tiered utilization and material recycling through refined battery management, improving battery utilization and profitability, and maximizing battery benefits.

Affected by users' work and life, the use of charging piles is currently mainly concentrated in certain time periods, increasing the burden on the power grid. In the battery swapping mode, swapping stations can serve as distributed energy storage units, allowing batteries to be charged during off-peak periods at night, which is conducive to peak shaving and valley filling of the power grid, reducing the impact on the power grid. Through Vehicle-to-Grid (V2G) technology, swapping stations can release surplus energy to the grid during peak daytime electricity consumption periods, acting as virtual power plants to assist the grid in meeting peak load demand, improving the utilization of power

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resources. Taking NIO as an example, during the summer of 2022 when there was a national shortage of electricity supply, 15 swapping stations in Hefei collectively participated in peak shaving operations as a "virtual power plant", adjusting the power load by 8MWh over five days without affecting normal swapping usage for users. Additionally, nighttime charging can also reduce charging costs. For example, in Beijing, for general industrial and commercial electricity users, the charging price is 1.42 yuan per kilowatt-hour during peak hours and 0.29 yuan per kilowatt-hour during off-peak hours, resulting in a difference of 1.13 yuan[10].

3.2. Challenges for Battery Swapping Stations Technology

3.2.1. Standardization Issues

Battery and Interface Standardization: Different manufacturers of new energy vehicles may use different battery sizes, shapes, interfaces, etc., which greatly limits the universality and interoperability of battery swapping technology. The lack of unified standards makes it difficult for battery swapping stations to accommodate all types of electric vehicles, increasing the complexity and cost of constructing and operating battery swapping stations.

Unified Technical Agreements: In addition to hardware standards, the lack of uniformity in software standards such as battery management systems and data exchange protocols is also a major obstacle, affecting the consistency of battery status monitoring, safety performance evaluation, and user experience.

3.2.2. Economic Viability and Cost Issues

High Initial Investment: Building a battery swapping station requires a large capital investment, including land, facility construction, backup battery packs, etc., which is a significant burden for startups or small businesses.

Operational Cost Challenges: The operation and maintenance of battery swapping stations, battery depreciation, updates, and management costs all require continuous financial support. As battery performance deteriorates over time and needs to be replaced regularly, it increases the long-term operating costs.

3.2.3. Technical and Safety Issues

Limitations of Battery Technology: The rapid development of battery technology means that today's advanced batteries may be outdated tomorrow. The compatibility issues brought about by rapid technological iterations pose challenges to the long-term application of battery swapping technology.

Safety Considerations: Improper operation or equipment failure during the repeated swapping of batteries may damage the batteries or even cause safety accidents. In addition, safety management during the long-term storage and use of batteries is also a major challenge.

3.2.4. Market and Consumer Acceptance

Consumer Habits and Acceptance: Despite providing a fast energy replenishment method, consumers still have concerns about the distribution of battery swapping stations, swapping speed, battery health, etc. Additionally, consumer attitudes towards owning their own vehicle batteries may also affect their acceptance of battery swapping services.

Market Competition and Technology Choices: In the field of new energy vehicles, besides battery swapping technology, there are various energy replenishment methods such as fast charging technology. The competition between these different technological paths and the varying market acceptance of them may affect the promotion and popularization of battery swapping technology.

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4. Recommendations for the Development of Battery Swapping Stations Technology

4.1. Standardization and Government Policy Support

Promote the industry to jointly develop and adhere to unified standards for battery modules and battery swapping station interfaces. This initiative aims to ensure that different manufacturers and brands of new energy vehicles can smoothly complete battery swaps at any swapping station, greatly enhancing user experience and industry efficiency. The government encourages corporate participation in the construction and operation of swapping stations by providing policies such as tax exemptions, subsidies, and research and development funding. Encourage pilot cities to increase financial support, research and introduce operational subsidies, road usage rights, electricity usage discounts, low/zero carbon emission zones, and other supportive policies to explore the establishment of a policy system that adapts to the development of new technologies and models. Establish a sound monitoring system for the safe operation of new energy vehicles and infrastructure, and enhance the level of safety in operation. Explore the formulation of standards and technical specifications for comprehensive energy service stations. In addition, policies should also encourage research and standardization of battery and related new energy vehicle technologies to promote the healthy development of the industry.

4.2. Technological Innovation and Safety Enhancement

Develop more efficient and automated battery swapping technology, including intelligent battery management systems that can monitor battery status in real-time to ensure swapping safety and battery lifespan. Continuously optimize battery designs to improve durability and safety, while developing advanced swapping equipment and processes to ensure the safety and reliability of the swapping process. Accelerate the application of new charging and swapping technologies such as intelligent orderly charging, high-power charging, automatic charging, and rapid battery swapping, and accelerate the pilot application of integrated "light storage and discharge". Explore the implementation path for new energy vehicles to participate in the electricity spot market, improve the mechanism for trading green electricity storage and discharge, promote the construction of intelligent travel and intelligent green logistics systems, promote the application of new technologies such as intelligent connectivity and vehicle-network integration, and accelerate the integrated development of new energy vehicles with energy, transportation, and other fields.

4.3. Construction of Extensive Battery Swapping Networks

Establish swapping stations in strategic locations such as city centers, commercial districts, major transportation arteries, and highway service areas, cooperating with existing facilities such as gas stations and large parking lots to introduce swapping services, effectively utilizing existing urban infrastructure, and accelerating the construction of swapping networks. Optimize the layout of public charging networks in central urban areas, strengthen the construction of charging and swapping infrastructure along highways, in suburban towns, and in intercity fast charging networks. Consider the charging needs of public transportation, taxis, logistics, postal delivery, etc., and strengthen the construction of dedicated charging and swapping stations such as parking lots. Promote the inclusion of charging and swapping facilities in municipal facilities, promote interoperability of charging operation platforms, and encourage the opening of internal charging piles to the public. Encourage the use of existing sites and facilities to build a batch of comprehensive energy service stations integrating charging, swapping, refueling, etc. Establish a networked, standardized, orderly, and efficient system for the recycling and utilization of power batteries.

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4.4. Innovation in Business Models and Market Promotion

Explore and implement diversified business models including battery leasing, monthly swapping subscriptions, etc., to meet the needs of different user groups and enhance the attractiveness and accessibility of swapping services. Increase publicity for battery swapping technology through various channels such as media, online platforms, public events, etc., to enhance public awareness and acceptance of swapping services. At the same time, emphasize the economic, convenience, and environmental advantages of swapping technology to promote consumer adoption of new energy vehicles.

5. Conclusion

Although China's battery swapping technology has achieved certain results, it is still in the developmental stage, and achieving widespread adoption poses significant challenges. The essence of the battery swapping model is to tap into the full life cycle value of power batteries and redistribute benefits to enterprises and consumers. Promoting the battery swapping model can bring multiple benefits to various stakeholders. Compared to charging, the battery swapping model holds a clear advantage in replenishment efficiency. Efficient replenishment and unified battery management can effectively improve the utilization of social resources, optimize user experiences in vehicle purchase and replenishment, and also align with the government's development needs under the context of the "dual carbon" goals. Therefore, the development of battery swapping technology is the general trend.

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