

Challenges and countermeasures in planning, building, and managing electric vehicle charging piles

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Abstract. The widespread adoption of new energy vehicles, particularly electric vehicles (EVs), has created a significant demand for charging infrastructure globally. China, a key player in the EV market, has made substantial advancements in charging pile technology and infrastructure development. However, several critical challenges threaten the sustainability and efficiency of the EV charging ecosystem. This paper identifies and analyzes these challenges, including insufficient planning and construction of charging piles, increased demand for electric energy affecting power grids, high construction costs of fast-charging infrastructure, regional disparities in investment returns, and operational management issues. Moreover, it explores potential strategies to address these challenges. Proposed strategies include optimized planning for charging pile construction, the creation of integrated vehicle-charging-pile platforms, the development of distributed energy systems using blockchain technology, promoting recycling and reutilization of waste charging infrastructure, continuous financial subsidies, and enhanced follow-up operation supervision. Addressing these challenges through comprehensive strategies is essential for China and other nations to establish robust and sustainable EV charging infrastructure, ensuring it meets the growing demand for new energy vehicles in the years ahead. This effort will contribute to a cleaner and more sustainable future for the transportation sector.

Keywords: Electric Vehicles, Charging Piles, Planning and Construction.

1. Introduction

New energy vehicles, especially electric vehicles, have been widely promoted and applied worldwide, which has led to significant demand for charging. In order to meet the increasing number of new energy vehicles, the construction and planning of charging piles have also been continuously improved and changed in recent years. The charging piles on the market are mainly divided into two types: DC charging piles and AC charging piles. With the strong support of national policies, China has achieved multiple breakthroughs in charging pile technology, and is constantly exploring more efficient and more rational arrangements in charging pile distribution. However, overall, China still faces many problems and challenges in the planning, construction, and management of charging piles, requiring a strategy in areas such as technological research and development, policy support, and management mechanisms to be devised to deal with them.

In 2020, the government work report of China included the construction of electric vehicle charging piles as one of the new infrastructure projects. According to the "Guiding Opinions on Energy Work in 2020" issued by the National Energy Administration, strengthening the construction of charging

infrastructure and improving the charging capacity of new energy vehicles is a clear task requirement. In terms of charging facilities, according to the statistics from China Charging Union [1], the incremental increase of charging infrastructure in China reached 936,000 units in 2021, with an increase of 340,000 public charging piles, up 89.9% year-on-year; while the number of private charging piles installed with vehicles surged, with an increase of 597,000 units, up 323.9% year-on-year. It is expected that the number of new energy vehicles in China will reach 64.2 million by 2030. According to the construction goal of a vehicle-to-pile ratio of 1:1, there is a gap of 63 million charging piles in China's construction in the next ten years [2].

2. Challenges Faced

2.1. *Insufficient Planning and Construction of Charging Piles to Meet Market Demand*

The unreasonable planning of some charging stations has led to a mismatch between the spatial layout and service capacity of charging stations and actual charging needs. The phenomenon of low utilization rate of charging stations and inconvenient charging for users has become a pain point in the electric vehicle industry. The reasonable layout planning of charging stations is the key to high-quality construction of charging piles, which can optimize the user experience and charging experience of electric vehicles, effectively improve the utilization rate of charging piles, and reduce the operational pressure on the urban electric vehicle transportation network and power network. As of the end of June 2019, the ratio of China's new energy vehicles to public charging piles was 6.8:1, and including private charging piles, the ratio reached 3.7:1 [3]. China's charging piles are mainly distributed in public underground parking lots, parking spaces in residential and office areas, gas stations, or expressway service areas. Among them, many unused charging piles are found in places such as shopping mall underground parking lots, while there is a problem of insufficient number and service of charging piles to meet market demand in some busy urban core areas with a high volume of pedestrian and vehicular traffic.

2.2. *Electric Energy Supply and Assurance Cannot Effectively Support Electricity Demand*

The significant increase in charging demand from electric vehicles will significantly increase the operational load of existing power grid facilities, so charging stations must be planned and constructed in advance. In core urban areas, where power supply is relatively tight, restrictive measures are generally taken for electricity consumption. For example, during the concentrated charging period of electric vehicles, it will form a large power load on the grid, leading to an impact on the electricity balance. Therefore, when conducting large-scale charging, the issue of power balance should be considered. Coordinated control should be increased for charging of electric vehicles to avoid overloading of circuits and regional distribution transformers, thereby improving the safety, reliability, and economic operation of the distribution network. In the specific process of connecting charging piles to the power grid, it will affect the voltage level of the distribution network. For example, when the grid is operating at low voltage, the reactive power and active power of the grid will increase. Therefore, it is necessary to avoid the unordered connection of electric vehicles to the grid for charging, especially during peak load periods, which will further increase the peak-to-valley difference of load and put pressure on the regional grid, ultimately affecting the quality of electric energy. According to research [4], when the penetration rate of electric vehicles exceeds 50%, it will lead to low voltage at some terminal nodes. For load-heavy end-user sections, the alternating supply between three phases will result in harmonics. Harmonics can affect the effectiveness of power flow calculation in the grid, increase network consumption, and cause additional consumption for high-voltage equipment. Harmonic effects mainly include electromagnetic interference and electrostatic effects on communication lines. For asymmetric transmission lines, both effects need to be considered, while for symmetrical transmission lines, only the electrostatic effect of high-order harmonics needs to be considered. Harmonic effects indicate the degree of pollution of the end-user side to the power grid, and the dynamic pollution of charging piles directly affects the stable and safe operation of the power grid.

2.3. High Construction Cost of Fast Charging Piles

Normal charging piles have a cost of around 2000 yuan, while fast charging piles have a cost of tens of thousands of yuan. Fast charging piles have an additional rectifier, which is very expensive. Tesla's high-power charging pile can achieve a maximum output of 240V/40A in single-mode charging, with a charging speed faster than that of ordinary household interfaces. It can charge 29 miles per hour. In dual-mode charging, it can output 240V/80A, with a charging speed of 58 miles per hour. The supercharging pile has an output voltage of 380V and a current close to 200A, with a charging speed of 220 miles per hour [5]. Fast charging and DC liquid-cooled supercharging technologies require high technical requirements, and cables with large current carrying capacity and rapid heat dissipation ability are needed for supercharging technology. These difficult technical requirements have pushed up the cost of charging piles.

2.4. Large Differences in Investment Returns for Construction in Different Regions

Generally, 7 kW slow chargers are installed in parking lots of shopping malls, office buildings, and other places, while 120 kW fast chargers are usually installed in parking lots of scenic spots, highways, and other places to facilitate plug-and-play usage. The initial battery level of slow charging users follows a uniform distribution of 0.3~0.7, while the initial battery level of fast charging users follows a uniform distribution of 0.3~0.4. The charging station is divided into dedicated charging stations and public charging stations. The constructed model mainly consists of two modules: construction cost calculation module and investment benefit calculation module. The construction cost calculation module calculates the construction cost from two aspects: the investment calculation of the charging station itself construction (including four parts: charging pile, circuit, power supply facilities, and civil construction) and the investment calculation of the system construction (including two parts: power supply line and system equipment). The investment benefit calculation module comprehensively calculates the investment benefits in different scenarios from several aspects such as input cost, electricity price, loan interest rate, depreciation, subsidies, service fees, and electricity efficiency gains. According to research [6], the general investment payback period in urban central areas is generally not more than 10 years, while the investment payback period in other non-core areas can reach more than 30 years.

2.5. Varying Levels of Operation and Management Services for Charging Piles

One is the problem of damaged charging facilities without repair. Currently, the inadequate maintenance and service capacity of electric vehicle charging facilities are universal problem in the charging pile operation industry. In August 2019, a CCTV media survey found that many users reported problems such as damaged charging piles, inability to use, and lack of maintenance in charging pile APPs. Second, the utilization rate of charging piles is not high. According to data from China's public charging piles in April 2022, the charging volume was 1.56 billion kWh, and the number of public charging piles was 1.419 million, resulting in an average utilization rate of approximately 5.2% per charging pile per day. The low utilization rate and profitability lead to a longer investment payback period. Third, there are many safety hazards, and industry standards still need to be unified. In recent years, incidents of new energy vehicles catching fire have occurred from time to time, and charging safety technology has become increasingly concerned by society. It is urgent to unify and standardize industry standards and improve the safety and compatibility of charging interfaces. Fourth, fuel vehicles "dominate" charging parking spaces. The shortage of parking spaces in Chinese cities has been a long-term problem. In addition, some parking spaces are motivated by interests and some car owners are not "disciplined", which often results in electric vehicle charging parking spaces being occupied by fuel vehicles. In July 2021, a reporter from Beijing Youth Daily came to the northern parking lot of Beijing Guimao Shopping Center to investigate and found that even though nearly one-fifth of the regular parking spaces were still available, all slow charging electric vehicle parking spaces were occupied, most of which were fuel vehicles, and only one new energy vehicle was being charged.

3. Suggestions for Countermeasures

3.1. *Do a good job in planning the construction of charging piles*

The construction plan should optimize the method of estimating the charging demand of electric vehicles from the "vehicle" and "station" perspectives. Focusing on the accuracy of charging demand estimation and the matching degree of charging stations with future demand in the field of charging station planning, research should be conducted on the coordinated use of the distributed energy storage and flexible charging and discharging characteristics of electric vehicles in the era of "vehicle-pile-road-network" interconnection. The Guangdong Provincial Energy Bureau released the "Development Plan for Electric Vehicle Charging Infrastructure in Guangdong Province during the 14th Five-Year Plan" [7], which clearly states that by the end of 2025, Guangdong will have built more than 4,500 centralized charging stations, about 250,000 public charging piles, including about 217,000 public charging piles and about 33,000 dedicated charging piles, about 830 fast charging stations on highways, and all expressway service areas in Guangdong will have charging infrastructure. The service radius of charging facilities in the core area of the Pearl River Delta region is no more than 0.9 kilometers, and the service radius of charging facilities in the core area of the eastern and western regions of Guangdong is no more than 2 kilometers. The ratio of public piles to vehicles is about 1:6.4.

3.2. *Building a Vehicle-Charging Pile Integrated Platform*

Vehicle-Charging Pile Integration is an effective solution and development trend for solving the problem of parking and charging [8]. By building a vehicle-charging pile integrated data platform, the original extensive management mode of vehicles, charging piles, and parking spaces is changed. Through data exchange, the resources of new energy vehicles, charging piles, and parking spaces are integrated, which can reduce ineffective traffic, improve traffic order, save energy consumption, enhance social benefits, promote the process of intelligent urban transportation, and provide more credible data for the government to formulate and implement new energy policies (such as optimizing the layout of charging piles). After arriving at the charging station/parking lot, users can recognize their license plates and authenticate their user accounts through a camera. After entering the parking lot, they can find a suitable parking space through the map guidance service provided by the operator. Users start charging and timing and billing by scanning the QR code. At this time, real-time parking time and charging data will be uploaded to the vehicle-charging pile integrated platform. The platform will send data to the operator for settlement function on one side and share data with the government urban brain for supervision and management of operators on the other side. It will also facilitate the later subsidy review and settlement related to the construction and use of charging piles. Relevant operational data can be shared with map software and other navigation tools through the urban brain, which is convenient for users to understand the availability of nearby charging stations and for transportation management to understand the charging and parking needs of various regions in the city, make timely scheduling and guidance, improve traffic efficiency, and avoid congestion. Therefore, the integration of vehicle and charging pile platforms can enhance user experience, facilitate operational decision-making for operators, strengthen supervision, and provide livelihood services, which is an effective measure that achieves multiple benefits.

3.3. *Construction of Distributed Energy Based on Blockchain Charging Piles*

The design of the ecosystem for energy trading based on blockchain charging piles is mainly composed of the following four groups [9]: first, producers and service providers are mainly responsible for the production relationship in the energy trading industry chain. Using blockchain technology to digitize and securitize assets, they realize the data information of all transactions in electricity production, storage, consumption, and delivery, and implement a transparent self-sufficient self-operating digital economy system for energy trading. On the other hand, they control the supply of electricity and develop control plans. Second, community consensus participants analyze the transaction data of charging piles and establish incentive mechanisms through smart contracts on the blockchain. Third, Dapps groups

promote the development of derivative business scenarios and improve the quality of services. Fourth, charging pile owners can be private individuals or company-level operators. They are the main constructors and contributors of charging piles and also the main participants in transactions.

The distributed energy system based on blockchain charging piles connects the production and demand sides, establishes a complete management mechanism for energy production, transmission, distribution, consumption, and trading [10]. The new charging pile brings the following advantages to the development of electricity: first, it reduces the dependence on traditional power generation; second, distributed power generation is generally "intelligent trading" to avoid excessive power loss; third, because electricity producers and consumers carry out mutual assistance trading, they adjust their own electricity consumption "elastic capacity" as much as possible, reducing the impact of new energy power generation on the power system; fourth, potential huge photovoltaic users can provide considerable electricity generation for blockchain distributed power generation, promoting the healthy development of the energy market.

3.4. Strengthening the Recycling and Utilization of Waste Charging Piles

The recycling and utilization of waste charging piles have important value. Fully utilizing the value of waste charging piles, promoting secondary utilization of waste charging piles, effectively reducing resource waste and environmental pollution, and promoting the development of the new energy vehicle industry. There are multiple ways to reuse waste charging piles. One is to repair and improve the charging pile to continue its use. The aging charging pile can be upgraded in performance and appearance by replacing components or improving its appearance. This approach not only reduces maintenance and modification costs but also extends the service life of the charging pile. Another way is to disassemble the charging pile and recover valuable materials such as batteries, wires, and charging controllers for reuse or sale.

3.5. Continuous Financial Subsidies

First, regarding the construction of charging station facilities, the current subsidy standards are based on a certain investment amount ratio or charging pile power. It is recommended to increase the subsidy ratio for charging infrastructure, expand the subsidy scale and scope, and increase subsidies for large-capacity charging stations and vehicle-to-vehicle communication devices to promote the transformation and modernization of the industry. Second, further increase investment in research and development of charging infrastructure. The construction of charging facilities is a long-term process that requires a large amount of funding support. Low enthusiasm among enterprises in investing will restrict the rapid development of the industry. Therefore, it is necessary for the government to consider increasing research and development investment, actively guiding enterprises to increase research and development investment, improving technological innovation capabilities, and accelerating the progress of key projects, including increasing subsidies for battery research and development, shortening charging time, prolonging battery life, building intelligent charging stations, etc. [11]. Third, subsidies or rewards can be provided for individuals building private charging facilities by using personal electricity price discounts, free gifts for achieving charging volume targets, and other methods to provide sufficient financial support and incentives for private charging facilities. Fourth, strengthen the overall planning of charging infrastructure construction, balance the construction of charging facilities in both core and non-core areas of cities, and appropriately over-build non-core area charging facilities to provide high-quality services and leave sufficient development space for non-core areas in the future.

3.6. Strengthening Follow-up Operation Supervision

Strengthen supervision of the entire chain of the new energy vehicle industry, strictly implement subsidies and safety control measures to ensure the healthy development of the industry. Promote its healthy development through effective regulatory measures and drive industrial transformation and upgrading. First, relevant financial management departments responsible for implementing subsidies should strictly supervise the subsidy review, publicity, and application process, and simultaneously

implement publicity in national relevant registration systems to clarify the specific content of subsidies and establish a post-subsidy inspection mechanism to regularly inspect the production and operation status of subsidized enterprises. Second, utilize big data technology to establish a monitoring platform for electric vehicle charging operation and maintenance to ensure monitoring of vehicle operation, charging equipment, and maintenance facilities status. At the same time, conduct big data analysis and research on charging facility quality data to track management of data quality. Operational data is linked to national platforms to innovate data sharing and supervision mechanisms.

4. Conclusions

In conclusion, the rapid growth of new energy vehicles, particularly electric vehicles, has brought about significant demand for charging infrastructure worldwide. China, as a leading player in this industry, has made substantial progress in charging pile technology and infrastructure development. However, several critical challenges remain that need to be addressed to ensure the continued success and sustainability of this sector.

Firstly, there is an issue of insufficient planning and construction of charging piles to meet market demand. Poorly planned charging stations have led to low utilization rates and inconvenient charging experiences for users. Effective spatial layout and planning are crucial to optimizing the user experience and reducing operational pressures on the electric vehicle transportation network and power grid.

Secondly, the increased demand for electric energy to support charging poses challenges to the existing power grid infrastructure. Coordinated control and careful consideration of power balance during large-scale charging are essential to ensure the safety and reliability of the distribution network. Furthermore, the harmonics and voltage issues caused by high levels of electric vehicle charging need to be addressed to maintain the stability of the power grid.

Thirdly, the high construction costs associated with fast charging piles are a barrier to widespread adoption. Technological advancements and cost reductions are needed to make fast charging more accessible and affordable for users.

Fourthly, there are disparities in investment returns for charging infrastructure in different regions, leading to longer investment payback periods in some areas. Balancing investment and returns is crucial to ensure the sustainable development of charging infrastructure.

Fifthly, there are challenges related to the operation and management of charging piles, including inadequate maintenance, low utilization rates, safety concerns, and the occupation of charging parking spaces by fuel vehicles. Standardization and improved management mechanisms are essential to address these issues.

To overcome these challenges, a comprehensive strategy is needed. This strategy should include:

1. Improved planning and construction of charging piles, with a focus on accurate demand estimation and coordinated use of distributed energy storage.
2. The development of integrated platforms that combine vehicle, charging pile, and parking data to enhance user experience, improve traffic order, and provide data for policy formulation.
3. The implementation of distributed energy systems based on blockchain technology to connect producers and consumers, reduce power loss, and promote the development of the energy market.
4. The promotion of recycling and reuse of waste charging piles to reduce resource waste and environmental pollution.
5. Continued financial subsidies and incentives to support the construction of charging infrastructure and encourage private investment.
6. Strengthened follow-up operation supervision and regulatory measures to ensure subsidy transparency and the quality of charging infrastructure.

Addressing these challenges and implementing these recommendations will be crucial for China, as well as other nations, to develop a robust and sustainable charging infrastructure that can meet the growing demand for new energy vehicles in the coming years. By doing so, we can contribute to a cleaner and more sustainable future for transportation.

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