An Optimal Design of Electric Vehicle Charging Piles Based on Time-space Sequence

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Abstract. In recent years, due to the increasing support from the state and the rapid development of the electric vehicle manufacturing industry, the quantity and quality of electric vehicles have been greatly improved, which has increased the efficiency of the use of clean energy and improved the urban environment. At the same time, the optimization of related supporting services for electric vehicles has also become a hot issue. With the popularization of electric vehicles in major cities such as Beijing and Shanghai, residents' demand for charging piles is increasing. Although many electric vehicle operators put forward the concept of "one vehicle, one vehicle", the use of charging piles still faces many social problems. On the one hand, the number of charging piles is small in some areas, and residents have no electricity; on the other hand, the construction of charging piles in some areas is unreasonable, resulting in low utilization efficiency. This article explores the mathematical relationship between the charging capacity of electric vehicles and the quantity of electric vehicles, the average daily mileage of vehicles, and the energy consumption per unit of mileage, and proposes an optimization plan for electric vehicle charging piles based on time series. "car-pile information base model", to obtain a more optimized AC charging pile construction program, to a certain extent solved the problem of electric vehicle charging. At the same time, a simulation of the program was carried out and the results showed that the program can quickly determine the reasonable number of AC charging piles and reduce investment risks, providing a powerful guarantee for the healthy, rapid and efficient development of electric vehicles.

1. Introduction

Due to the rapid development of new energy vehicles, the supporting facilities such as charging piles and charging stations also ushered in rapid development. According to the Ministry of Industry and Information Technology, as of the end of 2014, China had completed the construction of 723 charging stations and 28,000 charging piles, and the number of charging piles was much lower than the increase in sales of new energy vehicles. [1] In 2014, the production and sales volume of China's new energy vehicles reached 83,900 vehicles. The contradiction between the supply and demand of charging facilities has become increasingly prominent. However, in 2015, the number of charging stations planned to be built nationwide has reached 1,549, and the number of charging stations planned to be built has reached 240,000, a nearly 10-fold increase compared to 14 years. Beijing will build a charging

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circle with an average service radius of 5 kilometers in the downtown area; Tianjin will build 6,700 charging piles or charging interfaces and build 66 new charging stations; the number of charging piles in Shanghai will exceed 6,000 in 2015. [2] With the country's increasing support for new energy vehicles, an upsurge in the construction of a charging pile infrastructure has started across the country. Despite the rapid development of charging piles, an analyst estimates that the current ratio of vehicle piles is less than 3.3:1, which is much lower than the ratio of 1:1 piles. The delay in the construction of charging piles has affected the further development of new energy automotive industry. The rapid development of electric vehicles has eased the environmental crisis in big cities, reduced dependence on petroleum resources, and optimized the transportation structure, which is of great significance for green sustainable development. Charging facilities are an important part of the development of the electric vehicle industry and an important technical support. At present, the development of electric vehicles in China is very rapid and vehicles are increasing rapidly. However, charging facilities have always been a shortcoming that restricts their development. At present, the charge ratio for the charging infrastructure is approximately 4:1, and it is arduous to achieve a 1:1 target by 2020.

The overall demand for the charging capacity of electric vehicles is a key factor affecting the layout of AC charging stations.

Only after the charging capacity reaches a certain scale can AC charging pile construction be realized on a large scale. The amount of electric vehicle charging is related to factors such as the number of electric vehicles, daily average mileage of vehicles, and energy consumption per unit of mileage. [3] In different regions and industries, the demand for electric vehicles for endurance and charging time is not the same. The travel routes, daily mileage, and charging time for different types of electric vehicles and hybrid vehicles, such as private cars, utility vehicles, and public transport vehicles, are not the same. This is an important factor that needs to be taken into consideration when constructing a charging pile. For the placement of electric vehicle charging piles, the benefits of commercial operation are the key criteria for measuring the success of construction. It is necessary to consider both the construction cost and maintenance cost of charging piles and the benefits brought by operations. The construction location and scale of the charging pile will affect the waiting time and driving cost of the electric vehicle owner. Therefore, the site selection should take into account both the manufacturer's revenue and user experience.

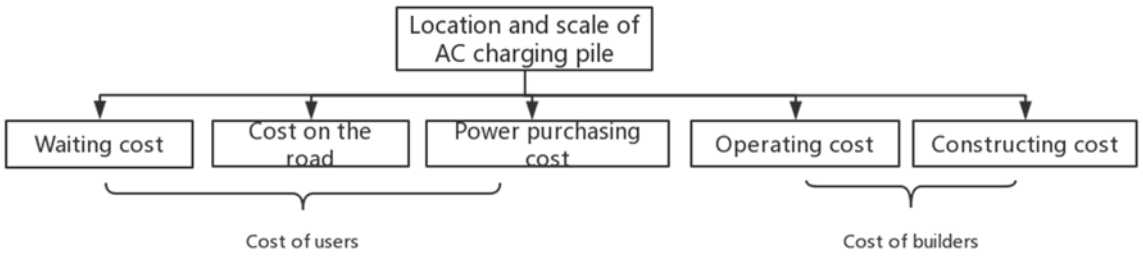


Figure 1. Cost analysis

2. Model establishment

According to the assumed AC charging pile information and the actual electric vehicle information, a vehicle-pile information base containing electric vehicles and AC charging piles is constructed. The AC charging pile information includes information such as the number of charging piles and the construction position. The electric vehicle information includes information such as remaining electric quantity, starting time, and corresponding position when starting all electric vehicles. By analyzing the status information of electric vehicle i at time t, the electric vehicle is guided to charge the most reasonable AC charging pile. The simulation process can determine the number and location of reasonable AC charging piles based on the number of electric vehicles in the area and related traffic information, which avoids additional costs due to multiple investment construction. Establish an AC charging pile construction model with the minimum total cost as the objective function.

The total cost of the objective function is the minimum, including the construction and management costs of the AC charging pile, the running costs of the electric vehicle on the road, and the charging waiting costs. The construction and management costs include pile construction fees, workers' working capital, and maintenance charges for AC charging piles. The objective function expression is:

$$\min f = \sum_{j=1}^{m}(U_{j0} + U_{j1}) + U_{i1}\sum_{i=1}^{n}\sum_{j=1}^{m} Z_{ij}d_{ij} + U_{i2}\sum_{i=1}^{n}\sum_{j=1}^{m} Z_{ij}t_{ij} \quad (1)$$

Where: n is the total number of electric vehicles, m is the total number of charging piles; Z_{ij} is the charging decision variable, when the i-th electric vehicle is charged at the j-th AC charging pile, its value is 1, otherwise it is zero; d_{ij} is the weighted distance from the i-th electric car to the j-th AC charging pile; t_{ij} is the waiting time for the i-th electric vehicle at the j-th AC charging station; U_{j0} is the construction and management fee for the j-th charging pile, and U_{j1} is the maintenance cost for the j-th charging pile. U_{i1} is the distance consumed by the electric vehicle, and U_{i2} is the unit cost of the electric vehicle.

The model is a dynamic model that fully considers the impact of various factors such as the distance from different electric vehicles to different AC charging piles and charging wait time, and the weighting coefficient is used in the modeling process, making the theoretical distance closer to the actual distance. In line with reality, the model is more accurate and reliable.

The objective function formula (1) contains three constraints: demand constraints, space constraints, and time constraints. Demand Constraint: Refers to whether electric vehicle i accepts the service of charging pile j, ie:

$$Z_{ij} = \begin{cases} 1 & accepted \\ 0 & not\ accepted \end{cases} \quad (2)$$

Space constraint: Set the coordinates of the AC charging pile to (X_j, Y_j), the car coordinates to be charged (x_i, y_i), where i=1,2..., j=1,2..., n, m=1 , 2..., the weighted distance is the actual travel distance possible:

$$d_{ij} = \omega_i\sqrt{(X_j - x_i)^2 + (Y_j - y_i)^2} \le d_{lim} \quad (3)$$

Time constraints: The waiting time for the i-th electric vehicle at the j-th AC charging pile must meet the following requirements:

$$t_{ij} = \begin{cases} 0 & N_{ij} = 0 \\ TN_{ij} & N_{ij} \ge 1 \end{cases} \quad (4)$$

The optimized layout plan is based on the collection of possible electric vehicle user behavior characteristics in a certain region, based on the electric vehicle charging load forecast to establish a possible "car-pile information base model", through the real-time update of electric vehicle driving status "car-pile information base model". Finally, the optimal distribution position of possible AC charging piles is obtained. For the optimization of AC charging piles in other regions, it is also necessary to analyze the behavior characteristics of the electric vehicle users in the region and establish a corresponding information base for this characteristic.

3. Summary

Based on the analysis of the total demand of electric vehicle charging capacity, the operating mode of electric vehicles under multiple scenarios, and the business operation mode of electric vehicle charging facilities, an AC charging pile construction model considering time constraints is proposed. Through the calculation of the cost of electric vehicles, such as the distance traveled by electric vehicles, the waiting charging time, and the construction and management of AC charging piles, a more optimized AC charging pile construction scheme was obtained, which resulted in the minimum charging comprehensive cost. The simulation results show that the program can quickly determine the reasonable number of AC charging piles and reduce investment risks, providing a strong guarantee for the healthy, rapid and efficient development of electric vehicles.

References

[1] Dong Zhenbin; Zhang Chongchao; Lin Yuming. Electric Vehicle Industry Technology and Promotion. Power Demand Side Management, 2015(02): 41-44.
[2] Wen Qing. Vigorously build charging facilities to solve the "last mile" problem. Automobiles and Safety, 2014.
[3] Wang Yang. Research on Charging Demand Characteristics and Charging Facility Planning Method for Pure Electric Buses. Beijing: North China Electric Power University, 2014.