Location Planning of Electric Vehicle Charging Station

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Abstract. The development of electric vehicles is not in harmony with the construction of charging facilities. In the development of electric cars, there is a general focus on the development and renewal of vehicles. But not too concerned about the construction of charging facilities, resulting in the phenomenon of cars without piles and piles without cars. The large-scale construction of charging facilities is a prerequisite for the popularization and application of electric vehicles. In the construction of charging facilities, location and capacity is an essential part. Reasonable planning of charging facilities can not only improve the convenience of EV users charging. It can also speed up the promotion and development of electric vehicles. It is of great significance to solve the problems of energy shortage and environmental pollution in China.

1. Introduction
In the early stage of the development of electric vehicles in China, the research on the layout and planning of the charging facilities for urban electric vehicles has just started. The research can draw on the method theory of the location planning of other facilities. The scale of electric vehicle charging station is studied in document [1]. Based on the distribution of residential area, the distribution of conventional charging demand is simulated, and the weight of each candidate site is allocated and modified according to the analytic hierarchy process. The optimal cost model is established based on the construction operation cost of the charging station, and the optimal cost model is used for the electric vehicle. The optimal distribution of the charging station is optimized. Document [2] based on the dynamic traffic network, the optimization model of the optimal scale and location of the electric vehicle charging station considering the hard time window constraints is constructed, and a two stage algorithm for solving the model is proposed.

Document [3] divides the planning of the charging station into three stages, and constructs the corresponding optimization model of charging demand according to the characteristics of different stages, and puts forward the planning model of EV charging station at different stages. The cost of each stage and the scale of the charging station have local optimal and extension points. Document [4] based on the principle of traffic conservation, derives the traffic density on the main traffic roads of the city, constructs the EV arrival rate model of the fast charging station, and constructs a planning model of the number and capacity of the charging pile of the EV fast charging station, combining the theory of queuing theory and the random service system.

Literature [5] considers the establishment of a dynamic traffic network simulation model, and considers the time and space constraints of the traffic model to obtain the optimal capacity and location of the electric vehicle charging station. In document [6], a two step method, which considers
environmental factors and service radius, is proposed to obtain possible candidate solutions for electric vehicle charging stations, and a multi-objective optimization model with investment cost, operating cost and network loss is solved by internal point method. Literature [7] first analyzes the idea and method of traditional facility location in detail, and evaluates and improves it. It puts forward a combination of game theory and site selection of charging station to optimize the location model, and constructs a quantitative and scientific model of optimal evaluation of the planning and location of charging stations. In document [8], a new type of location and capacity model for charging station is constructed with the minimum objective function as the related cost of the charging station (operating cost, net loss cost and equipment investment cost). In document [9], an optimized layout model of the charging station is innovatively constructed. The model not only considers the charging demand and charging behavior of the electric vehicle users from time and space, but also takes into account the dynamics and randomness of the whole traffic network.

The development of electric vehicles is at an initial stage, and the planning of the relevant energy supply network is still in the exploratory stage. In recent years, the planning of charging facilities for electric vehicles has become the focus of attention in the industry and academia. The layout planning of electric vehicle charging facilities mainly focuses on the location and capacity of charging facilities. Literature [10] combined with the common charging station location planning model, and improved the existing research constraints, and proposed a more scientific model for the location planning of electric vehicle charging station. Document [11] puts forward the necessity of the construction of electric vehicle charging station. The construction needs of the charging station should be integrated, diversified and networked to meet the requirements of the consumers. The location model of two electric vehicle charging stations is described in detail in document. One is to capture the traffic flow at the maximum limit of the fast charging station as the target, and the model two focuses on the construction cost of the charging station. Finally, the two models are analyzed by taking the location of the Barcelona city's charging station as an example. Due to the early development of the electric vehicle industry, the layout planning of urban electric vehicle charging facilities is relatively mature. Document not only discusses in detail how to build the network of electric vehicle charging facilities, as well as the characteristics and applicable objects of various charging facilities, but also describes how to build various charging facilities and the conditions needed to meet the requirements. In document, the demand for the construction of charging facilities based on different regions was divided and discussed, and the cost assessment and comparison of various types of charging facilities were carried out. In document, a new multi-objective programming model is built in this paper. The model takes into account the charging facilities and related information, the characteristics of the charging users, and how to coordinate the relationship between the construction of the charging facilities and the urban construction planning and the layout of the urban grid. On the basis of the research on the location selection of traditional facilities, on the basis of the maximum distance of the total distance or the maximum distance from the facilities to the demand point, is the optimization goal to rationally plan the location of the single or multiple facilities within the network. His research has further improved the theory of location selection and promoted the application of the theory in the actual scope. Literature gives a summary of the existing facilities location problem, lists a series of classical facility location models, and on the basis of these models, the analysis and expansion are carried out by adding different constraints. On the basis of the basic principle of network planning, literature constructs a new location selection model, which is the objective function of the square sum of the distance from the demand point to the facility location, and combines the actual situation to analyze and expand.

2. The best balance between charging station service capability and investment cost

From a mathematical point of view, the planning of electric vehicle charging station is a typical problem of location and capacity of service facilities. In the field of traffic and mathematical research, there has been a perfect location theory to help decision-makers or analysts weigh different planning goals, or to analyze the effects of different constraints on the location and capacity of service facilities.
The demand for services in transportation networks is generally assumed to be location specific location based location requirements. Based on location demand theory, the main goal of location selection in transportation networks is to maximize the location based demand. The goal of the charging station planning model is to maximize the service flow of electric vehicles on the road:

$$\text{Maximize : } F_1 = \sum_{q \in Q} f_q v_q$$

(1)

In the form: q is the shortest path from the starting point 0 to the end D; Q is a set of all paths; fq is the traffic on the path Q. F1 comprehensive investment cost.

$$F_2 = \frac{r_0 (1 + r_0)^n m}{(1 + r_0)^m - 1} (A_i C_i + N_c C_c + N_t C_t + C_F)$$

(2)

In the form: M is the planning period; r0 is fixed annual rate; N_c and C_c plant represents the number and installation of the charger and the cost of the purchase; C_F represents the fixed charge of the charging station; A_l and C_l produce land use and price; N_t and C_t represent the number and unit price of the transformer.

The charging station planning model considering the growth rate of electric vehicles, the capacity limits of electric vehicles and the capacity constraints of distribution networks are considered. The construction of charging stations at random will not lead to the increase of the distance of electric vehicle owners and the mileage of electric vehicles. The difference in battery capacity of electric vehicles will result in the planning of charging stations. The battery capacity of electric vehicles, traffic network topology and electric vehicle form are incorporated into the planning of electric vehicle planning, and the limit of battery capacity will be an important factor affecting the planning results of the charging station.

3. Minimization of system network loss and voltage offset

When the new electric vehicle charging station is connected to the distribution system, the distribution of the power flow will change. The network loss of distribution system will be changed. The loss of distribution system should be considered reasonably in the planning of charging stations. The charging of electric vehicles will also lead to the change of node voltage offset, which will affect the safe and stable operation of the distribution system. It is the two optimization goal to reduce system loss and reduce voltage offset.

(1) Minimization of distribution system network loss

When a large number of electric vehicle charging stations are connected to the distribution network, the distribution of the distribution network changes immediately. It will further affect the network loss of the entire distribution network. The network loss is mainly related to the load distribution, so the network loss will change after the charging station is connected to the grid. The specific changes are also closely related to the location and capacity of the charging station. The objective function of the minimum loss of the distribution system is as follows:

$$\text{min} S_{\text{us}} = [P_{\text{loss}} (U_i, P_{Si}, U_i, Q_S)]$$

(3)

In the form: P_{Si} and Q_S are the active capacity and reactive power capacity of electric vehicles when they connect to the I node respectively. U_i indicates whether to build an electric vehicle charging station at node i. 1 and 0 respectively indicate construction and non construction. According to the relevant research, when the charging station is connected to the distribution system, it will cause the node voltage to shift. The voltage offset of the distribution system will be used as an indicator of the
location planning of the charging station, and the node voltage offset can be used to express the voltage difference between the node voltage and the balance node.

The calculation formula is as follows:

$$\min V_{dp} = \left[ \sum_{i=1}^{m-1} \gamma_k \frac{|V_k - V_0|}{V_0} \right]$$

(4)

In the form: m is the number of nodes in the distribution system; V_0 is the balance of the node voltage; V_k is the voltage of the node K; \( \gamma_k \) is a weight coefficient; The value can be determined according to the importance of nodes, and the importance of nodes can be determined by running the power saving load. The calculation formula is that P_i is the original load of the node K. \( P_{load} \) is the total load of the distribution system.

4. Optimal capacity of charging station

The number of charging stations in a station is reasonably allocated, the quantity of which is determined by the number of electric vehicles and the behavior of vehicles. The research is based on queuing theory and according to the traffic cut by charging stations built on various routes. Under the premise of meeting customer’s charging demand, we consider the waiting time of customers and the utilization ratio of charging piles to plan the optimal capacity of electric vehicle charging stations. Under the premise of reasonable utilization rate of the charging station, the shorter the user’s waiting time, the higher the customer satisfaction. If the number of the charging piles is \( i \), the number of electric vehicles obeys the Poisson distribution of the parameter of \( \lambda \). The time of the electric vehicle to accept charging is set to the negative exponential function of the parameter \( u \).

The electric vehicle queuing model is a multi service model (M/M/S), and the utilization rate of charging facilities I is: its value must be less than 1.

The average time of stay of customers in the charging station \( W_s \) is:

$$W_s = \frac{[\sum_{k=0}^{i-1} \left( \frac{\lambda}{u} \right)^k \frac{1}{k!} + \frac{(\lambda/u)^i}{\lambda(1-\rho_s)^i}] \rho_i}{\lambda^2(1-\rho_s)}$$

(5)

Set up the customer satisfaction function as follows:

$$M = \alpha \left( \frac{W_s}{W_{max}} \right)^{-1} + \beta \times \rho_i$$

(6)

Among them, \( W_s/W_{max} \) is the labeling process of waiting time, and the purpose of saving coefficient is to increase the proportion of utilization. The purpose of \( \alpha \) and \( \beta \) is to increase the proportion of utilization.

The development of electric vehicles is not in harmony with the construction of charging facilities. In the development process of electric vehicles, the development and renewal of vehicles are generally paid attention to, but the construction of charging facilities is not concerned. The cause of this incongruity is reflected in two aspects, one is that the size of electric vehicles in some areas is growing rapidly, but the construction of the charging facilities is completely unable to keep up with the pace; the two is due to the lack of correct cognition of the electric vehicle and the protection policy in some areas. The charging load of large-scale electric vehicles will inevitably affect the operation safety of distribution network in many ways. Therefore, when the power grid planning is built, the load carrying capacity of the existing distribution network lines and equipment should be analyzed, and the position and capacity constraints of the electric vehicle charging load access to the power grid should be
studied. The large-scale construction of the charging facilities is the prerequisite for the popularization and application of electric vehicles.

In the process of the construction of the charging facilities, the location and capacity of the charging facilities is an essential part. Reasonable planning of charging facilities can not only improve the convenience of electric vehicle users, but also accelerate the promotion and development of electric vehicles. It is of great significance to solve the problem of energy shortage pressure and environmental pollution in China. As an important part of new energy strategy and smart grid, electric vehicles must coordinate with other fields to achieve coordinated development. The electric vehicle charging and changing power station is the basic facility for the energy supplement of the electric vehicle. As the electric vehicle industry in our country is still in the early stage of development, the corresponding charging facilities have an important influence on its popularization.

5. Summary
The goal of multi-objective planning for electric vehicle charging station is to determine the position and capacity of the charging station according to some optimized target functions and meet the related constraints. It is generally assumed that the electric vehicle charging station planning is responsible by the electric power company. The goal is to meet the charging needs of electric vehicle owners in the case of electric vehicle driving needs and battery capacity. The operation target of distribution network, such as reducing the system network loss caused by the electric vehicle charging power flow, or maintaining the stability of the distribution system or the traffic system, will also be taken into consideration.

The distribution network planning problem is divided into two parts: one is to minimize the loss of the distribution system and the offset of the node voltage, and the other is to maximize the service capacity of the charging station by the capture of the electric vehicle traffic. Taking into account the interests of the charging station operators and electric vehicle users, a new model for the location and capacity of the electric vehicle charging station is set up with the maximum benefit of the charging station, the minimum charge cost of the user and the minimum cost of the comprehensive investment. The traffic flow and maximum charging power as well as the type of battery charging station and the battery capacity of electric vehicle are the constraints.

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