Research on Location and Layout of Electric Vehicle Charging Facilities Based on Power System Dispatch

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Abstract. In order to enable the limited charging stations in the road network to meet as many demands as possible, and to give full play to the advantages of electric vehicles in changing the energy consumption structure and reducing greenhouse gases, a dual-objective charging station optimization problem is proposed. The paper uses the shortest path and the next-shortest path to describe the traffic flow factors in the traffic network. The goal is to maximize the traffic flow intercepted by the charging station, minimize the investment cost of the charging station and minimize the node voltage offset, and establish electric vehicle charging Station multi-objective planning model. The results prove the effectiveness of the proposed method and provide decision support for enterprises to scientifically and reasonably select the location of charging stations.

Key words: Power system dispatch, electric vehicle charging pile, location selection.

1. Introduction
In recent years, many cities in China have fallen into a "smog crisis." The exhaust gas produced by the combustion of gasoline and diesel has become the pollution source with the highest proportion in cities, especially the crude oil consumption in the freight industry is staggering, and the development of new energy freight transportation is imperative. The popularization of electric vehicles can effectively reduce environmental pollution and dependence on fossil fuels. However, it is difficult to achieve large-scale promotion of electric vehicles at present. The main obstacles are the limited number of charging stations, short cruising range, and high purchase cost. Some studies have found that the cruising range of electric vehicles has a negative effect on consumers' desire to buy and satisfaction, especially for long-distance travellers. In order to promote the promotion and application of electric vehicles and the further expansion of the market scale, it is necessary to build a corresponding charging facility service system. The existing charging facilities cannot meet the long-term development needs of electric vehicles, and even hinder the rapid expansion of my country's electric vehicle industry [1]. Reasonable charging facilities the problem of constant capacity layout needs to be solved urgently. This paper studies the constant capacity layout of public charging stations and charging piles.
2. The impact of charging methods on the grid

2.1. Distributed charging
This charging method is mainly affected by user behavior factors. The choice of when and where to charge is completely subjectively determined by the user, which is extremely random and unpredictable. Since the voltage required for this charging method is low, it is no different from a household appliance, and the charging is not centralized, so the impact on the power grid can be basically ignored. This charging method is slow to charge, and is characterized by dispersion, multiple points, and freedom. It is mainly aimed at low voltage (380V/220V) plug-and-charge charging points. The distributed charging current is generally $0.2 \sim 0.5C$ ($0.5C$ means $1/0.5=2h$ full charge in an ideal state), and it takes 5-8h for the battery state of charge (SOC) to increase from 0 to 100%.

2.2. Centralized charging
Refers to the unified charging of large-scale electric vehicles within a certain period of time, generally including battery replacement and fast charging. The fast charging current is several times larger than the distributed charging current. Usually, high-power DC charging is used, which can increase the battery's SOC in a short time. Centralized charging at peak load times will cause partial load overload in the distribution network, disrupt the grid load balance, and even affect the safe operation of the power system [2].

2.3. Smart charging
According to whether to feedback electric energy to the grid, the intelligent charging mode is divided into intelligent unidirectional orderly charging mode (VIG) and intelligent two-way orderly charging and discharging mode (V2G). Among them, V2G refers to the electric vehicle as a load connected to the grid while also serving as a distributed energy storage device, which can feed back the electric energy stored in it to the grid in time. Using this feature, when the power grid is in peak hours or the power grid fails to operate normally, electric vehicles can be used to reversely transfer electrical energy to the power grid to provide temporary power support. The smart charging mode is conducive to optimizing the operation of the power grid, and to a certain extent guarantees the reliability and continuity of power supply when the power grid fails.

3. Charging station planning model

3.1. Model objective function
The model proposed in this paper establishes an objective function based on the maximum traffic flow intercepted by the combination of charging stations, the minimum investment cost of charging stations and the minimum node voltage deviation. Maximize intercepted traffic flow:

$$\text{Max}_{f_1} = \sum_{q \in Q} \sum_{r \in R_q} f_{qr} y_{qr}$$

In the formula: $q$ is a pair of starting point O and ending point D; $Q$ is the set of all node pairs; $r$ is the factor representing the shortest path or the second shortest path; $R_q$ is the set of the shortest path and the second shortest path between node pairs $q$; $f_{qr}$ is the traffic on the shortest path between the node pair $q$; $g_{qr}$ is the proportion of car owners who are willing to use the path $r$ to travel between the node pair $q$; $y_{qr}$ is whether the traffic on the path $r$ between the node pair $q$ can be intercepted by the charging station, if it can It is 1, otherwise it is 0.

Minimize the investment cost: In the model used in this article, the assumed cost includes three aspects: one is the construction cost of all charging stations, the other is the expansion cost of the power node, and the third is the operation of the charging station after it is built. Network loss costs [3].

$$\min f_2 = \sum_{k \in K} c_{1k} x_{k,d} + \sum_{i \in N} c_{2i} x_{i,d} + c_3 P_{loss}$$

(2)
Where: $k$ is the candidate position of the charging station; $K$ is the set of all candidate positions; $x_{s,k}$ is whether the charging station is built at the candidate position $k$, if the charging station is built, it is 1, otherwise it is 0; $i$ is the power node; $N_i$ is The set of all power nodes; $x_{s,i}$ is whether the $i$-th power node needs to be expanded, if it needs to be expanded to 1, otherwise it is 0; Ploss is the network loss of the distribution system; $c_{1,k}$ and $c_{2,i}$ are the construction of the charging station at $k$ The cost coefficient and the cost coefficient of the $i$-th power node expansion [4]. $c_i$ is the network loss cost coefficient of the power network. In this model, it is assumed that these three parameters are all externally given constants.

Minimize node voltage offset:

$$
\min f_3 = \sum_{i \in N_0} \gamma_i \left( \frac{V_i - V_0}{V_0} \right)
$$

Where: $V_i$ is the voltage of node $i$, $V_0$ is the voltage of the balance node, and $\gamma_i$ is a weighting factor that indicates the importance of node $i$.

3.2. The construction of the double constraint objective weighting problem

The key to the parameter method is to construct a single objective function reasonably. In each construction process, the coefficients generated by the target vector $(f_a, f_b)$ given in the first-in first-out list are used to perform the linear combination of the objective function, where $f_a = (f_{n1}, f_{n2})$, $f_b = (f_{s1}, f_{s2})$. The specific formula is as follows

$$
\min_x f = w_1^{(s)} f_{n1}^1 + w_2^{(s)} f_{n2}^1
$$

Obey constraints:

$$
f_{n1}^1 \leq f_{n1}^{\max} - \varepsilon, \quad f_{n2}^1 \leq f_{n2}^{\max} - \varepsilon
$$

among them,

$$
\begin{align*}
 f_{n1}^{\max} &= \max \left( f_{n1}^1, f_{n1}^2 \right) \\
 f_{n2}^{\max} &= \max \left( f_{n2}^1, f_{n2}^2 \right) \\
 w_1^{(s+1)} &= \frac{f_{n1}^2 - f_{n1}^1}{f_{n1}^1 - f_{n1}^2 + f_{n2}^1 - f_{n2}^2} \\
 w_2^{(s+1)} &= \frac{f_{n2}^1 - f_{n2}^2}{f_{n1}^1 - f_{n1}^2 + f_{n2}^1 - f_{n2}^2}
\end{align*}
$$

The method of generating parameter set $w = (w_1^{(s)}, w_2^{(s)})$ is called orthogonal method, which was proposed by Cohon for the problem of bi-objective linear programming. Since the study of this paper is a discrete problem, the feasible target area is discontinuous, so additional constraints: $f_{n1}^1 \leq f_{n1}^{\max} - \varepsilon$ and $f_{n2}^1 \leq f_{n2}^{\max} - \varepsilon$, need to be introduced to each objective function to ensure the non-inferiority of the solution.

4. Simulation analysis

According to the above model, the decentralized charging facilities in the core area of the city are planned for 2020. The city's core planning area has 75 functional areas, including 25 residential areas, 25 commercial areas, 15 office areas, and 10 leisure areas. The locations of these areas are randomly generated in the plane coordinates. There are 5 charging stations that have been built. Figure 1 is a plan location map. Among them, numbers 1-25 are commercial areas, 26-40 are office areas, and 41-50 are
leisure areas. Table 1 shows the specific data of the demand forecast of charging facilities corresponding to the functional areas numbered 1-50 in Figure 1 when calculating the optimal configuration.

![Plane location map of each functional area](image)

**Figure 1.** Plane location map of each functional area

The model only plans for electric vehicle charging facilities in functional areas other than residential areas. In 2020, the parameters of electric private vehicles in the planned area are $\rho=1.3$, $\gamma=100\%$, $\mu=70\%$, $\delta=1$, and its penetration rate by the target planning year $\omega$ is expected to be $5\%$. References for parking space construction standards and floor area ratios in different types of functional zones, and relevant parameters for demand forecasting are shown in Table 2. According to the specific data of charging demand forecast in Table 1 and formulas (1)-(5), the demand for charging piles in each functional area of the planning area can be obtained, and the total demand is calculated to be 820.

### Table 1. Specific data of demand forecast

| Function area number | $d$/km | Area/m$^2$ | Function area number | $d$/km | Area/m$^2$ |
|----------------------|--------|-----------|----------------------|--------|-----------|
| 1                    | 0.43   | 13 823    | 26                   | 2.87   | 4135      |
| 2                    | 2.15   | 38 249    | 27                   | 5.87   | 5277      |
| 3                    | 4.37   | 7693      | 28                   | 4.82   | 5411      |
| 4                    | 6.2    | 25 307    | 29                   | 3.61   | 5413      |
| 5                    | 4.83   | 25 915    | 30                   | 7.3    | 4787      |
| 6                    | 2.53   | 66 641    | 31                   | 0.03   | 3975      |
| 7                    | 3.47   | 18 477    | 32                   | 4.08   | 5245      |
| 8                    | 6.74   | 36 807    | 33                   | 1.16   | 4429      |
| 9                    | 5.01   | 33 904    | 34                   | 4.04   | 4547      |
| 10                   | 2.18   | 58 355    | 35                   | 4.55   | 4440      |
| 11                   | 4.12   | 6136      | 36                   | 5.14   | 4272      |
| 12                   | 7.11   | 56 253    | 37                   | 1.66   | 3528      |
| 13                   | 1.39   | 40 151    | 38                   | 2.72   | 3842      |
| 14                   | 6.56   | 7956      | 39                   | 2.62   | 5633      |
| 15                   | 1.45   | 38 400    | 40                   | 4.92   | 5622      |
| 16                   | 0.78   | 33 966    | 41                   | 4.73   | 51 511    |
| 17                   | 0.25   | 36 939    | 42                   | 5.5    | 62 597    |
| 18                   | 0.08   | 47 893    | 43                   | 1.33   | 73 180    |
| 19                   | 7.74   | 37 849    | 44                   | 5.22   | 18 302    |
| 20                   | 7.1    | 53 221    | 45                   | 6.15   | 60 390    |
| 21                   | 0.4    | 66 350    | 46                   | 3.17   | 23 525    |
| 22                   | 5.36   | 56 956    | 47                   | 3.17   | 11 017    |
| 23                   | 7.81   | 33 452    | 48                   | 5.54   | 11 071    |
| 24                   | 1.76   | 10 870    | 49                   | 1.9    | 94 287    |
| 25                   | 0.67   | 65 682    | 50                   | 7.59   | 54 418    |
In the initial stage, the number of candidate sites in the functional zone for installing charging piles is 20, and the number of site sites is limited to 15. After actual investigation, functional areas 1, 6, 9, 12, 13, 17, 19, 22, 23, 24, 25, 27, 28, 29, 33, 36, 41, 42, 46, 47 are initially selected as new facilities Candidate site. The coverage radius of the charging facility is 0.9km, with the maximum coverage demand as the goal, the candidate sites are determined as 1, 9, 12, 13, 17, 19, 23, 25, 28, 33, 36, 42, 46. In the service range of two types of facilities, customers are considered to choose charging stations. However, since these functional areas are the addresses of newly built charging facilities, it is believed that customers will choose charging piles in the functional areas for charging [5]. Figure 2 shows the charging station and the specific service objects of each newly built charging facility. It can be seen that due to the limited number of resources and candidate sites, functional areas 8, 22, 32, 41, 48, 49 are not in the service range of charging facilities, but the model achieves the largest demand coverage.

| Functional area    | Volume rate | Standard/(Bit·m⁻²) | Area distribution/m²       | Average mileage/km |
|-------------------|-------------|-------------------|-----------------------------|-------------------|
| Business district | 2.4         | 0.015             | U (5000, 70 000)            | U (0, 8)          |
| Workspace         | 1           | 0.008             | U (3000, 6000)              | U (0, 8)          |
| Recreation area   | 1           | 0.013             | U (5000, 100 000)           | U (0, 8)          |

**Figure 2.** Service objects of charging facilities

It can be seen from Figure 3 that with the increase in the installation cost of charging piles, the average arrival rate of vehicles at public charging stations gradually increases, and the average queuing time increases slightly from 12.3 minutes to 14.4 minutes. The total charging capacity of public charging stations is in as the total charging capacity of charging piles is constantly increasing, when the installation cost reaches 180 yuan, almost no users choose charging piles. As the installation cost of charging piles increases, the total charging cost of public charging stations is increasing. The total cost of pile charging increases first and stays near the maximum when the installation cost is 30-60 yuan, and then continues to decline [6]. All the overall costs are increasing, and the increase is decreasing. The total charging cost of public charging stations increases because of public charging stations Attracting more electric vehicles, causing the cost of queuing time to increase; the total cost of charging pile charging increased first because of the increase in the installation cost of charging piles, and then decreased because the total attracting capacity of charging piles was declining at this time. How many vehicles choose charging piles.
5. Conclusion

The centralized access of large-scale charging stations to the distribution network will cause serious voltage harmonics, voltage deviations and transformer overloads, which will lead to unbalanced loads in the distribution network. At the same time, it will also bring additional pressure to the power generation, transmission and distribution systems, and bring severe challenges to the safe and reliable operation of the power grid. The use of orderly charging and time-of-use electricity prices can effectively reduce the operation and maintenance costs of charging stations and user consumption costs under the conditions of meeting the changing needs of electric vehicles and overloading the transformer. At present, the research on the location and capacity planning of charging stations is mainly focused on the urban transportation network, mainly considering geographical factors, traffic factors, population, urban planning factors, economic factors and environmental safety factors. For the highway transportation network, the location planning of the charging station is mainly based on the goals of the longest electric vehicle mileage, the maximum traffic flow, the minimum life cycle cost of charging station construction and operation, and the highest electric vehicle user satisfaction.

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