IOP Conference Series: Materials Science and Engineering

Location and Capacity Planning of Electric Vehicles Charging Piles

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Abstract. As the planning and construction of electric vehicle charging pile plays a decisive role in the promotion of electric vehicles, this article puts forward a planning method considering the cooperation of different types of charging piles and analyzes the Residential and social charging piles. On the basis of determined number of charging piles in residential area, the planning of social charging piles is analyzed from the demand of charging considering the unbalance of electric vehicles' promotion, the location of charging piles considering the minimum charge distance and the capacity of charging piles considering the situation that EVs don't charge every day. And then the processes of planning are determined. Finally, the planning method is applied to a Xincheng planning in ZhuoZhou which could illustrate the feasibility of this method. Compared with other method, the method of this article pays more attention to the actual situation from the load forecast to the overall planning in the area, thus the result is more realistic and in line with the planning requirements.

1. Introduction

Due to its great advantages in environmental protection, energy saving and emission reduction, electric vehicles have already begun to be promoted in major cities in China. In the next few years, domestic pure electric vehicles will occupy a larger market in the automotive sector [1-3]. With the increase in the number of electric vehicles, the demand for charging infrastructure is also increasing. The construction of charging piles has become an important factor restricting the development of electric vehicles. Charging pile planning has become a hot issue [1, 4].

In the current research, the charging pile planning is mostly based on site selection and capacity. It is mainly based on the existing urban pattern[5], traffic flow information[6] and distribution network structure[7], considering the physical area division and The power network structure and other factors constrain the planning of charging piles and achieved great results. Literature [8] proposed a two-step optimization location method for the location of electric vehicle charging stations in the city, analyzed the charging requirements of the road sections and the urban traffic network, and comprehensively assessed the location of charging stations. The literature [9] analyzed the traffic. And power construction constraints, determine the location of the charging piles, and based on energy equivalence to predict load, determine the capacity of the charging piles and complete the site selection of the charging piles; literature [10] considers traffic flow, urban roads and other factors, and The grid constraints are added to the constant volume of the electric vehicle charging piles, and the constraints of the node voltage amplitude and access to the grid power are taken into account to determine the charging pile power. The literature [11] determines the site of the charging station based on the urban road and uses the queuing theory to determine The number of chargers. However, the current research mainly focuses on social charging piles, and does not consider the complementary relationship between household charging piles and public charging piles, which affects the overall planning.

Under the above background, this paper proposes a charging pile planning method in which the charging pile interacts with the public charging pile in the residential area. Firstly, it analyzes the influence of the unbalanced development of the electric vehicle on the planning and determines the charging demand; then, the social charging pile is given as auxiliary charging. The location of the facility was determined based on the location of the charging pile. Finally, the impact of the charging time of the electric vehicle on the charging load was considered to determine the capacity of the charging pile. Finally, the location of the charging facilities in Zhuozhou Xincheng in 2025 was taken as an example to illustrate the proposed method.

2. The whole charging pile planning steps

The “Guiding Opinions on Accelerating the Construction of Electric Vehicle Charging Infrastructure” issued by the State Council at the end of 2015 pointed out that the construction of charging facilities should be based on the user-owned parking spaces and the special charging facilities installed in the unit parking lots, and public parking facilities should be built. Charging facilities are auxiliary to form a three-dimensional electric vehicle charging infrastructure system. This requires that the demand for electric vehicle charging be met at the city level through the planning of electric vehicle charging piles in the community and charging piles outside the public parking lots outside the community.

In view of this, this paper proposes a three-dimensional charging pile planning method, which divides the charging pile into two types: the charging pile in the community and the public quick charging pile. The community charging piles mainly provide the slow charging service for fixed users. Due to the relatively fixed location of parking spaces, the relatively concentrated charging time, and the long time for slow charging, the charging piles in the residential area are mostly dedicated for buses and need to be based on the penetration rate of electric vehicles. Construction within the community.

The public charging pile is mainly used to meet the charging requirements caused by the imbalance of the charging pile's supply and demand. It needs to pass through factors such as unbalanced supply and demand of the charging pile, characteristics of the vehicle trip, mileage, battery capacity, power consumption per hundred kilometers, whether it is a daily charge, and other factors. Conduct the analysis. For unbalanced charging requirements, model the objective function with the shortest charging distance and determine the location of the common charging pile. Considering the situation of multiple days and one charge, the charging load within the charging pile coverage is predicted so that the capacity of the public charging pile needs to be met. The charging demand of the electric vehicle at the time of maximum charging load determines the number of charging piles. The planning process of public quick charging piles is shown in Figure 1.

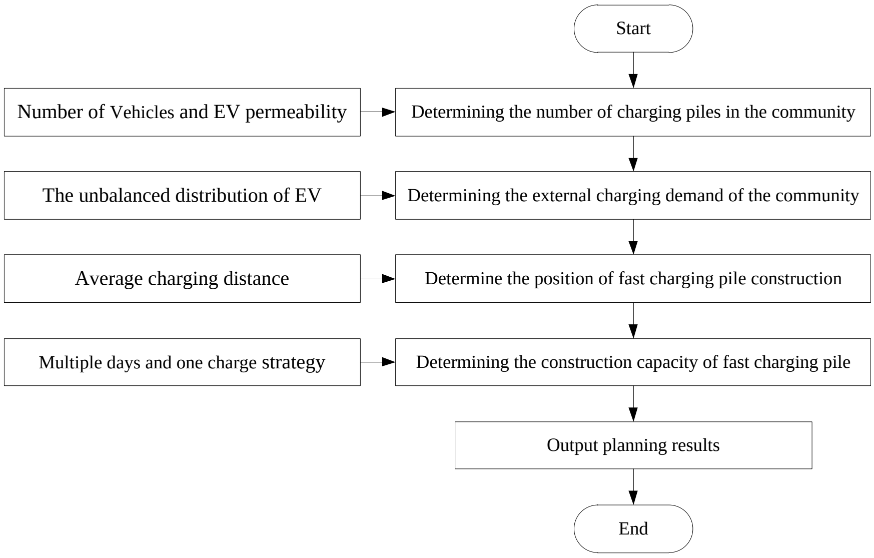

Figure 1. The flow chart of fast charging piles planning.

3. Charging pile planning method

3.1. Determination of charge requirements in consideration of unbalanced distribution of electric vehicles

The number of electric vehicles can be determined by the number of parking spaces planned by the community, the utilization rate of parking spaces, and the penetration rate of electric vehicles. According to the guidance, slow charge piles must be built at a ratio of 1:1. However, the unbalanced distribution of electric vehicles will cause the actual number of electric vehicles in the community to deviate from the predicted value, resulting in a conflict between supply and demand between electric vehicles and charging piles. Given the current domestic housing situation, it will be more difficult to park vehicles in other districts for charging for a long time or to purchase parking spaces in other communities. This requires the construction of a public charging pile to meet this demand for charging. For each cell, the distribution of electric vehicles is not balanced, and Monte Carlo simulation can be used to determine the charging requirements.

Assume that there is a car in the community and the probability of the electric car is P, and the vehicle is determined according to the number of electric vehicles in the community. The above process was repeated 10,000 times and statistics were taken to determine the distribution of the distribution of electric vehicle numbers.

For a normal distribution, there is a 99% probability that the random variable is distributed within the interval $[\mu - 3\sigma, \mu + 3\sigma]$, so the confidence limits can be used to estimate the upper and lower limits of the number of electric vehicles. Among them, the difference between the upper limit of the number of electric vehicles and the average value is the maximum unbalanced number of vehicles that may occur is the charging demand. In the case of a certain average sample size, the maximum number of unequal vehicles in the overall area is:

$$Q = \frac{1}{2} \times 3 \sum_{i=1}^{N} \sigma_i \tag{1}$$

N is the number of Residential areas in the area, and σ_i is the variance of the statistical results of the number of EV in the residential area.

3.2. Location planning of public charging pile based on minimum charging distance

Charging distance is the distance from the electric car to the nearest charging pile. According to the charging demand and charging distance of each community, the optimal location and service scope of public charging pile construction are determined.

3.2.1. Charging pile position planning model. If a certain area contains a plurality of charging pile construction points that can be used to charge an electric vehicle, the electric vehicle in the area always selects the charging point that is nearest to its own construction point, which divides the entire area into multiple small sub-domains. Each small area is the range of load requirements that the charging pile should meet within the corresponding construction site, that is, its service scope.

(1) Objective function.

The planning goal of the electric vehicle charging pile in a certain range is that the sum of the weighted total distances of the individual cells reaching the charging pile is the smallest. The objective function is:

$$f(x) = \min\left(C_i \sum_{i=1}^{n} \sum_{j=1}^{m} \min S_{i,j} \right) \tag{2}$$

$\min S_{i,j}$ is the distance from the i th cell to the nearest one of the m charging and construction points, C_i is the number of electric vehicles in the i th cell, and m is the number of electric vehicle construction points.

(2) Constraints

a. Public charging pile location constraints

The public charging piles are mainly built in public parking lots, so the location of the selected public charging piles must be within the scope of public parking lots, that is, the location of public charging piles:

$$(x,y) \in A \tag{3}$$

Where A is the parking location coordinate set.

b. Parking lot constraints

Since the number of parking lots is limited, the number of parking lots needs to be constrained, that is, the number of parking lots is constrained:

$$m \le M \tag{4}$$

M is the total number of parking lots.

3.2.2. TLBO optimization algorithm. The TLBO algorithm simulates the process of teacher teaching and student learning, and achieves optimization through the two stages of “teaching” and “learning”. This method has many advantages such as high computational accuracy, fast convergence speed, small computational complexity, good global convergence for nonlinear optimization, and no constraint on algorithm parameters. It can solve optimization problems by setting the number of populations and termination conditions [12-14]. In view of the fact that the optimization goal in the paper is single-objective and requires a fast convergence speed, the TLBO algorithm is used to solve the optimization problem. In this paper, taking the coordinates of the proposed site as a variable, the minimum total charging distance is the optimization goal; the algorithm flow is shown in Figure 2.

3.3. Taking into account the determination of the charging capacity for multi-day charging

One-day charge limits the user's freedom to reduce the difficulty of calculation, but it will cause the waste of the battery. Literature [15] proposes an orderly charging strategy for electric vehicles based on the needs of individual consumers and the willingness of users. According to the National Travel Survey (England 2014), respondents who traveled less than 2 times per day reached 59.91%, and 98.25% of respondents had fewer than 5 daily trips. . For each trip, less than 8 kilometers of travel accounted for 66% of the total travel. According to relevant survey data, 84.25% of users have daily mileage of less than 60 km [16, 17]. When electric vehicle cruising range is 300 km, the daily power consumption of these users only accounts for 20% of vehicle battery capacity. Charging mode will cause a great waste of battery capacity, and does not meet the habits of most users. Therefore, it should consider the situation of multiple days and one charge.

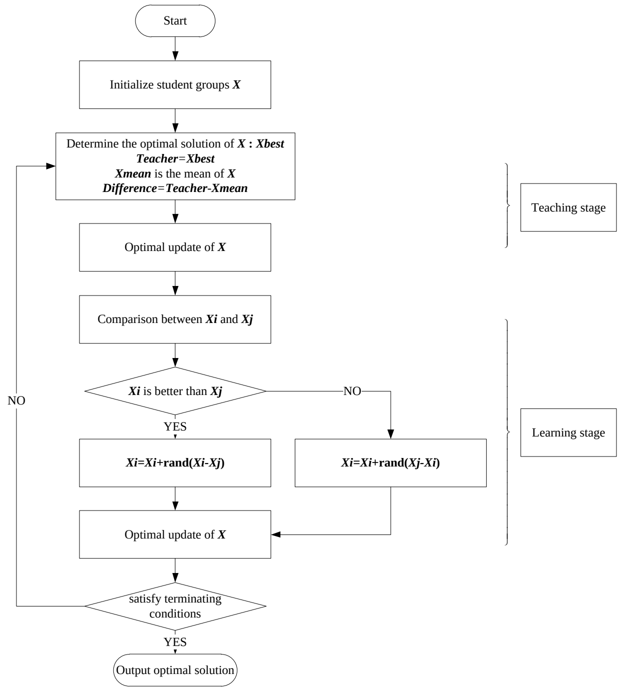

Figure 2. The flow chart of TLBO algorithm.

3.3.1. Electric vehicle charging judgment basis. Considering the case of multi-day charging, it is necessary to determine whether or not the electric vehicle is charged every day. Based on the initial charging power of different electric vehicles, it is determined whether or not the battery is charged on the day, and the charging probability is set to pc.

$$p_c = \begin{cases} 0 & x > 90\% \\ f(x) & 50\% < x \le 90\% \\ 1 & 0 < x \le 50\% \end{cases} \tag{5}$$

Where f (x) is the charge probability function, and its value is determined by the remaining charge x, which is set to satisfy Equation 6:

$$f(x) = \begin{cases} 0.2 & 80\% < x \le 90\% \\ 0.4 & 70\% < x \le 80\% \\ 0.6 & 60\% < x \le 70\% \\ 0.8 & 50\% < x \le 60\% \end{cases} \tag{6}$$

3.3.2. Determination of charging miles for electric vehicles.

The mileage of an electric vehicle is directly related to its charging load. If the electric vehicle is set to charge once a day, the daily mileage is the required charging mileage. When a multi-day charge is involved, the electric mileage should be the total mileage since the last charge. Therefore, the total mileage needs to be calculated. The total mileage is S:

$$S = (((S_n \times w_n + S_{n-1}) \times w_{n-1} + S_{n-2}) \times w_{n-2} + ... + S_0) \times w_0 \tag{7}$$

Among them, Sn is the mileage of the electric vehicle in the first n days and wn is the total mileage of the corresponding days. It can be determined by Formula $w_n = f(p_n)$.

4. Analysis of case calculation

Taking the planning of the charging piles of the high-speed railway Xincheng in Hebei Province as an example, the Xincheng is in the planning and construction stage. There are 52,940 parking spaces in the residential area, divided into 41 areas, and the utilization rate of parking spaces in the residential area of Xincheng is expected to reach 90% by 2025. The penetration rate of electric vehicles is 20%. According to the 20% of the number of parking spaces, each community shall reserve the construction of the exchange of slow charging piles and construct DC fast charging piles in public parking lots.

4.1. Charge demand determination

According to the method proposed in Section 2.1 of the article, the maximum number of unbalanced electric cars in each district can be obtained by judging the cars in the community. The results obtained are shown in Table 1.

Table1. Unbalanced number of vehicles (UNOV).

UNOV	No.	UNOV	No.	UNOV
29	15	29	29	15
32	16	25	30	31
24	17	17	31	29
19	18	16	32	26
19	19	24	33	27
19	20	21	34	26
16	21	22	35	27
19	22	0	36	28
18	23	0	37	36
18	24	0	38	35
16	25	0	39	28
15	26	0	40	18
23	27	12	41	23
15	28	17		

4.2. Charging pile site selection

Taking the charging demand of each cell as the weight and minimizing the total charging distance as the optimization goal, the TLBO optimization algorithm is used to determine the optimal construction location of the public parking lot. According to the actual project requirements, the number of available parking lots is 2 to 5, and the construction site location and division are shown in Figure 3. The total charging distance and the number of parking lots are shown in Table 2.

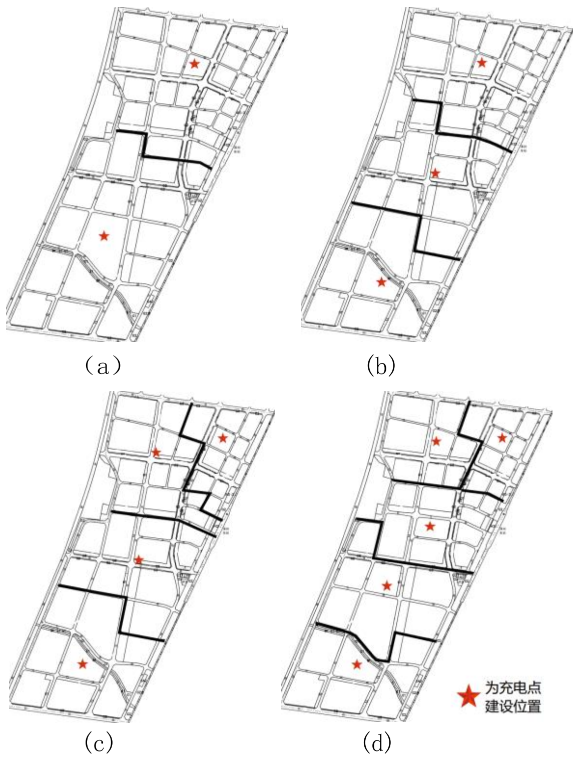

Figure 3. Different construction point location.

Table2. Charge distance of different construction points.

Construction points number	Charge distance/km	Total distance reduction percentage
2	516.2	----
3	401.3	22.25%
4	347.2	13.49%
5	308.3	11.20%

According to the percentage change of the total distance reduction, project construction needs and investment restrictions, select option (b) to build 3 public charging parking lots as the final planning plan. This scheme has a smaller total charging distance, and at the same time, on the basis of the same purchase cost of the charging pile, taking into account the smaller reconstruction cost of public parking lots, and is suitable for application in the charging pile planning of the high-speed railway Xincheng in Zhuozhou City, Hebei Province.

4.3. Determine the charging pile power

Considering the situation of multi-day charging, forecast the charging demand within the service range, use the Monte Carlo method to predict the charging load curve of fast charging piles in public parking lots, and determine the number of charging piles to meet the charging requirements within the range. In this article, 24 hours a day is divided into 96 time points, and the arrival time of vehicles in the community is shown in Equation 12.

$$y = 0.595e^{-\frac{(x-73.77)^2}{2.17^2}} + 0.405e^{-\frac{(x-77.67)^2}{3.77^2}} \tag{8}$$

The statistics of the number of trips per sunrise are shown in the table 3.

Table3. The statistical results of Daily travels.

Travel times	Percentage	Travel times	Percentage
0	6.63%	6	3.49%
1	17.86%	7	1.16%
2	34.70%	8	0.41%
3	22.99%	9	0.16%
4	4.72%	10	0.01%
5	7.86%	11	0.01%

5. Conclusion

This paper proposes a method for considering the location and constant volume of charging piles that are complemented by different types of charging piles. The planning of charging piles and public charging piles in the residential area is considered separately, and the following research work is mainly completed.

(1) The classification of electric vehicle charging piles has been proposed, and a charging demand determination method that takes into account the unbalanced distribution of electric vehicles has been proposed.

(2) The optimization model of the charging pile location targeting the shortest charging distance of the charging user is proposed, and the TLBO algorithm is applied to the optimization calculation of electric vehicle charging pile location.

(3) Proposed to take into account the charging load of electric vehicles for several days

With the prediction method, the results obtained are closer to the actual situation than the original setting.

Through the research on the layout planning of the charging facilities for the high-speed railway Xincheng in Hebei Province, the practical application of this method is introduced. The current charging pile planning system is still not perfect, and more is at the theoretical level. With the increasing number of electric vehicles entering major cities and the increase in charging data for electric vehicles, this kind of three-dimensional sub-type planning method will also be further improved.

References

[1] YANG Xi,DENG Jianshen,LI Hongfeng,FANG et al. Design and research on public service and interactive platform in electric vehicle[J].Power System Protection and Control,2016, 44(10):137-144.

[2] Mohsenian-Rad A, Wong V W S，Jatskevich J, R et al. Autonomous demand-side management based on game theoretic energy consumption scheduling for the future smart grid[J] . IEEE Trans. on Smart Grid, 2010, 1(3) 320-331.

[3] LU Xinyi，LIU Nian，CHEN Zheng，et al. Multi-objective optimal scheduling for PV-assisted charging station of electric vehicles [J]. Transactions of China Electrotechnical Society, 2014, 29(8):46- 56.

[4] XU Qingqiang, KOU Yinggang, MA Jianwei, et al. Research on typical design scheme of charging/battery swap infrastructure for electric vehicle[J].Power System Protection and Control,2015, 43(13):118-124.

[5] LIU Zhipeng, WEN Fushuan, XUE Yusheng, et al. Optimal siting and sizing of electric vehicle charging stations [J]. Automation of Electric Power Systems，2012， 36(3): 54- 59.

[6] WU Chunyang, LI Canbing, DU Li, et al.Typical schemes of electric vehicle charging infrastructure connected to grid [J]. Automation of Electric Power Systems, 2010，34(24) : 37-45.

[7] WANG Hui, WANG Guibin, ZHAO Junhua, et al. Optimal planning for electric vehicle charging stations considering traffic network flows [J]. Automation of Electric Power Systems，

2013, 37 (13): 63- 69.
[8] GAO Yajing， GUO Yandong. Optimal location of urban electricvehicle charging stations using a two-step method [J]. Electric Power, 2013, 46(8): 143-147.
[9] GUO Chunlin, XIAO Xiangning. Planning method and model of electric vehicle charging infrastructure [J] . Automation of Electric Power Systems, 2013，37(13): 70- 75.
[10] HUANG Xiaoqing， YANG Hang， CHEN Jie ， et a1. Optimal planning for electric vehicle charging stations based on life cycle cost and quantum genetic algorithm[J]. Automation of Electric Power Systems, 2015, 39(17): 176-182(in Chinese).
[11] ZHAO Shuqiang, LI Zhiwei. Optimal Planning of Charging Station for Electric Vehicle Based on PSODE Algorithm [J]. Journal of North China Electric Power University,2015, Vol. 42, No. 2: 1-7.
[12] Rao R V, Savsani V J, Vakharia D P. Teaching-Learning-Based Optimization: An optimization method for continuous non-linear large scale problems[J]. Information Sciences, 2012, 183(1):1-15.
[13] Satapathy S C, Naik A, Parvathi K. Weighted Teaching-Learning-Based Optimization for Global Function Optimization[J]. Applied Mathematics, 2013, 04(3):429-439.
[14] Rao R V. Applications of TLBO Algorithm and Its Modifications to Different Engineering and Science Disciplines[M].// Teaching Learning Based Optimization Algorithm. 2016.
[15] DANG Jie, TANG Yi, NING Jia, et al. A strategy for distribution of electric vehicles charging load based on user intention and trip rule[J]. Power System Protection and Control,2015,43(16):8-15.
[16] Darabi Z, Ferdowsi M. Aggregated impact of plug-in hybrid electric vehicles on electricity demand profile [J]. IEEE Transactions on Sustainable Energy, 2011, 2(4):501-508.
[17] ZHANG Dexin, CHEN Jinchuan, LIU Ying. Daily travel characteristics and the development strategy of private motor vehicles in Beijing [C]// Proceedings of the6th International Conference of Transportation Professionals. Dalian: Press of Dalian University of Technology,2006.(in Chinese).