The most preferred location planning for electric vehicle charging stations considering harmonic pollution based on vehicle behavior simulation

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Abstract: With the continuous implementation of China’s energy conservation and emission reduction policies, the number of electric vehicles in cities is also increasing. In order to ensure the stable and rapid development of the electric vehicle industry, it is necessary to reasonably build electric vehicle charging stations to meet the vehicle charging requirements. Reasonable location and volume can improve the charging convenience of electric vehicle owners and improve the service life of electric vehicle batteries. In this paper, the charging requirements of electric vehicles are divided into three levels. And Markov chain is used to describe the behavioral information such as driving state, parking position, driving mileage and remaining electricity to obtain different charging requirements. The mathematical model is established with the goal of maximum coverage and consideration of factors such as harmonic pollution. In this paper, genetic algorithm is used to find the optimal charging station location.

1. Introduction
Reasonable electric vehicle charging station location and constant capacity can improve the convenience of electric vehicle owner charging and improve the service life of electric vehicle battery. Therefore, in the electric vehicle charging station location and constant volume process, the battery characteristics of electric vehicles need to be one of the factors considered. In addition, during the operation of the charging station, it will cause a certain degree of harmonic pollution to the transmission power grid. Therefore, in the construction of the charging station, it is necessary to fully consider these factors to protect the distribution network.

In literature [1], the continuous Markov chain model is used to study how to increase the peak load of the system while maximizing the benefits of the grid by formulating an orderly charging control method when the power supply capacity of the grid is limited and the charging behaviour is controllable. In literature [2], the Markov chain is used to describe the diversified car habits with three states, to determine the specific charging demand at each moment. To complete the charging pile planning with the goal of small operating cost. In literature [3], the service demand partition is compared by comparing the service radius. The location of the vehicle recycling site is optimized by using the large cover-
age model. The above research has reference significance for this paper. However, the dynamic behaviour of the vehicle and the charging service of the charging station for various charging requirements are not systematically considered. The harmonic pollution caused to the transmission grid during the operation. Based on this, this paper analyzes the behaviour of vehicles, uses Markov chain to describe the behaviour information such as driving status, parking position, mileage and remaining power to get different charging requirements; establish charging judgment criteria to meet different charging needs. The position of the candidate charging station is obtained statistically; the number of charging stations is reasonably selected to reduce the harmonic pollution to the transmission network. In order to ensure the rationality of the location, a large coverage model is established and the genetic algorithm is used to find the location of the excellent charging station based on the candidate site.

2. Electric vehicle behaviour simulation

2.1. Vehicle state simulation

In order to analyze the state of the electric car used or parked in a day, this paper describes the random use of the vehicle through the Markov chain. Divide the day into 24 time periods, assuming that the electric car in each time period can be in one of the following four states: moving (M), parking in the residential area (R), parking in the commercial area (C), Parked in the industrial zone (I). Expressed in . At each time, the vehicle may switch to another state or continue to maintain the original state. The transition of state t and j at time t may be the state transition probability in equation (1). Expressed in $P_{i \rightarrow j,t}$:

$$P_{i \rightarrow j,t} = P(S_{i,t+1} = j | S_i = i)$$  \hspace{1cm} (1)

2.2. Vehicle parking position prediction

After determining the usage state of the electric vehicle for each period of time, the actual position of the vehicle in the simulation area is determined. The next time position (destination) is determined according to the current location (departure place), and the judgment rule is shown in the table 1.

| Previous moment state | current state | Driving destination |
|-----------------------|---------------|---------------------|
| R                     | R             | Random determination|
|                       | C or I        | Random determination|
| C                     | R             | X1, n               |
|                       | C or I        | Random determination|
| I                     | R             | X1, n               |
|                       | C or I        | Random determination|

In Table 1, the travel distance of the vehicle can be randomly generated. According to reference [4], the average distance per vehicle is 15.52 km, and the randomly generated distance $d$ obeys a normal distribution with a mean value of 15.52 and a standard deviation of 5.17, which can be expressed as:

$$d \sim \text{normrnd}(15.52, 5.17)$$  \hspace{1cm} (2)

The charging demand judgment criteria summarized into Table 2.
Table 2. Charge demand judgment rule

| Charging grade | Charging site   | Charge demand judgment                                    |
|----------------|-----------------|------------------------------------------------------------|
| LV1            | Uptown          | $St,n=R, SOCa,n<50\%, Xt,n=X1,n$                          |
| LV2            | Charging station| $St,n=C, I, SOCa,n<50\%, tstay>tcharge$                   |
| LV3            | Charging station| $St,n=M, SOCa,n<20\%$                                      |

3. Electric vehicle charging station location selection

3.1 Charging station coverage based on consumption

The main road map of a city in the north as shown in Figure 1, through the $B_j, C_j, D_j$ intersection, there are a variety of driving routes to reach the destination.

Most of the current research is to plan the location of electric vehicle charging stations by path length. However, when the temperature and altitude are different, the same electric vehicle travels the same distance, and the power consumption is generally different. It is more reasonable to describe the service range of the charging station by using the power consumption. The electric vehicle power consumption model is established based on the following three points, and the power consumption $E$ is obtained.

1) Power equation

\[
\begin{align*}
    P_b(t) - P_p(t) &= P_c(t) \cdot \eta \\
    P_c(t) &= P_1(t) + P_2(t) \\
    \eta &= \eta_1 \cdot \eta_2 \cdot \eta_3 \cdot \eta_4
\end{align*}
\]

where: $P_b(t)$ is battery power, $P_p(t)$ is battery parasitic power, $P_1(t)$ is related to vehicle travel speed, air resistance, body mass and altitude, $P_2(t)$ is related to body mass and speed of cars. It has something to do with acceleration. $\eta$ is related to battery efficiency, motor conversion efficiency, control efficiency, mechanical transmission efficiency, etc.

2) Location information for the start and end points

3) Driving time
In order to facilitate the charging station planning for an area, the user address and charging station location in the area are handled as follows:

1) Suppose $R$ is a set of demand points, $R = \{1, 2, \ldots, i, \ldots, M\}$. There are $M$ demand points in a certain area and the location information of electric vehicles in the same area is the same. Take the center of the area as:

$$U = \{u_1, u_2, \ldots, u_i, \ldots, u_M\}$$

(4)

2) Most car owners go to and from homes and companies, homes and schools, homes and shopping malls, etc. This paper uses places with high traffic volume as potential locations for charging stations. Suppose $Q$ is a set of demand points, $Q = \{1, 2, \ldots, j, \ldots, N\}$. There are $N$ demand points in a certain area.

3.2 The most preferred location of Charging station

Assume that all the locations in the trunk road map are equipped with charging stations. According to the vehicle behavior simulation and charging judgment criteria, the number of times that each node can perform the second and third level charging modes is counted. The more the number of times, the more the vehicle generates the charging demand at this point. The more the number of times, and the more times the point can provide the charging service, the more the node position is selected as the candidate charging station site. In this paper, aiming at the large degree of coverage of the charging demand in the region, the objective function is:

$$X, L, C2i, C3i, N2$$

3.3 Model solving

Through the vehicle usage sample and the two-stage location method, the genetic algorithm is used to solve the construction position of the excellent charging station. The process is shown in Figure 2:
Start
Input the number of charges planned for construction Ncs
Reading analog system data and traffic network data
Establishment of a sample of Random use of electric vehicles
Assume that there are charging stations at all locations in the road network. Further vehicle charging location
Select the position where the vehicle charges the most times as the candidate charging station
Using the candidate site as the parent
Solving the maximum coverage Model by genetic algorithm
Whether to complete 50 Monte Carlo simulations
Y
Increase the number of times by one
N
Start
Input the number of charges planned for construction Ncs
Reading analog system data and traffic network data
Establishment of a sample of Random use of Electric vehicles
Assume that there are charging stations at all locations in the road network. Further vehicle charging location
Select the position where the vehicle charges the most times as the candidate charging station
Using the candidate site as the parent
Solving the maximum coverage Model by genetic algorithm
Whether to complete 50 Monte Carlo simulations
Y
Increase the number of times by one
N

Figure 2. Optimal charging station construction location solution flow chart

4. Case study

In this paper, taking a certain area as an example, according to the functions of each part in the area to be planned, it is divided into residential area, commercial area and industrial area, as shown in Figure 1. The selection of the construction location of the electric vehicle charging station is carried out by the method described above.

It is known that the number of charging stations allowed to be built in this area is 6 and 12, which are planned as two cases. When the first step of the planning is completed, the number of times each point is selected as a candidate charging station can be obtained. The statistics are shown in FIG. 2 and FIG. 3, respectively.

Table 3. Case counts the number of candidate charging stations in each case

| Node | 1  | 4  | 7  | 10 | 13 | 15 |
|------|----|----|----|----|----|----|
| 1    |    |    |    |    |    |    |
| 2    |    |    |    |    |    |    |
| 3    |    |    |    |    |    |    |
| 4    |    |    |    |    |    |    |
| 5    |    |    |    |    |    |    |
| 6    |    |    |    |    |    |    |
| 7    |    |    |    |    |    |    |
| 8    |    |    |    |    |    |    |
| 9    |    |    |    |    |    |    |
| 10   |    |    |    |    |    |    |
| 11   |    |    |    |    |    |    |
| 12   |    |    |    |    |    |    |
| 13   |    |    |    |    |    |    |
| 14   |    |    |    |    |    |    |
| 15   |    |    |    |    |    |    |
| 16   |    |    |    |    |    |    |
| 17   |    |    |    |    |    |    |
| 18   |    |    |    |    |    |    |
| 19   |    |    |    |    |    |    |
| 20   |    |    |    |    |    |    |
| 21   |    |    |    |    |    |    |
| 22   |    |    |    |    |    |    |
| 23   |    |    |    |    |    |    |
| 24   |    |    |    |    |    |    |
| 25   |    |    |    |    |    |    |
| 26   |    |    |    |    |    |    |
| 27   |    |    |    |    |    |    |
| 28   |    |    |    |    |    |    |
| 29   |    |    |    |    |    |    |
| 30   |    |    |    |    |    |    |
| 31   |    |    |    |    |    |    |
| 32   |    |    |    |    |    |    |
| 33   |    |    |    |    |    |    |
| 34   |    |    |    |    |    |    |
| 35   |    |    |    |    |    |    |

Figure 3. Area to be planned
| Number of choices | 50  | 36  | 26  | 35  | 27  | 27  |
|-------------------|-----|-----|-----|-----|-----|-----|

Table 4. Case two counts the number of candidate charging stations in each case candidate charging stations in each case.

| Node Number | 1  | 4  | 7  | 10 | 13 | 15 | 17 | 21 | 23 | 27 | 29 | 30 |
|-------------|----|----|----|----|----|----|----|----|----|----|----|----|
| Number of choices | 50 | 50 | 50 | 21 | 43 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |

According to the information in Figure 2 and Figure 3, the location of the candidate charging station is obtained. And then the charging station position is optimized. Table 5 shows the level 2 and level 3 charging requirements recorded after 50 Monte Carlo simulations in two cases. The number of times, the number of times the service was obtained, and the value of the objective function.

| Case | Station node | $N_i$ | $\sum_{i=1}^{N_i} f_i$ | $N_1$ |
|------|--------------|-------|----------------------|-------|
| One  | 1, 4, 7, 10, 13, 15 | 1699.5 | 880.85 | 156.8 |
| Two  | 1, 4, 7, 10, 13, 15, 17, 21, 23, 27, 29, 30 | 1583.5 | 1393.6 | 86.5 |

5. Conclusion
In this paper, the Markov chain is used to simulate the vehicle behavior information. According to the vehicle behavior simulation and charging judgment criteria, the node position with more times is determined as the candidate charging station site. This paper establishes an objective function of charging service coverage and uses genetic algorithm to solve the address of excellent charging station service. The location of the charging station is determined by the analysis of two different schemes in the actual traffic network. The effectiveness of the method of location selection of the electric vehicle charging station based on vehicle behaviour simulation is verified. The scheme one reduces the number of charging piles, which reduces the pollution of the harmonics to the grid.

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