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Capacity configuration of electric vehicle charging facilities based on user behavior prediction

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Abstract. By analyzing the behavior of electric vehicle users, this paper predicts the driving and charging activities of electric vehicles in the area and simulates the total charging load of electric vehicle charging load in a charging station in a certain area. Finally, taking a city as an example, this method is used to calculate the specific configuration scheme of the city's public charging network, and further studies the impact of user charging habits and vehicle differences on the configuration results. The results show that the proposed capacity allocation method is effective and feasible.

1.Introduction

With the increasing energy shortage and environmental pollution in China, electric vehicles as an important part of new energy applications and smart grids, its development trend has been irresistible. In order to meet the demand for charging of electric vehicles, The research of charging pile becomes more and more important. One of the key points in the improvement of electric vehicle charging facilities is the capacity configuration.

The capacity configuration of EV is closely related to the type of EV, charging characteristics and travel demand, while the type of EV directly determines the battery characteristics and travel demand. The authors in [1] attempts to describe the day-to-day operating characteristics of electric vehicles through a typical distribution. By observing the flow and working characteristics of the charging station, a service model of the charging station is established in [2] to determine the charging load of the fast charging network. The above research doesn't consider the fast charge and slow charge load as a whole, so it can't form a complete charging network configuration scheme. In this paper, the user behavior is analyzed to simulate the running and charging of electric vehicles in the area, and the ratio of fast charging and slow charging is studied.

2.Establishment of load forecasting model

2.1 Modeling steps

(1) The total number of certain types of electric vehicles in the predicted area and their charging capacity and power are determined.

(2) In order to obtain the charging data of these electric vehicles, a statistical model between the user behaviour and power demand of the electric vehicle in the predicted area is established. The charging



data includes initial charging time and initial charging capacity SOC. According to the above statistical model, the probability distribution of the initial charging time and the initial charging capacity SOC of this kind of electric vehicles are determined respectively.

(3) According to the probability distribution of the initial charging time and the initial charge capacity (SOC) of this kind of electric vehicle, the initial charging time and the initial charging capacity are randomly generated. Each pair of initial charging times and initial charge capacity SOC represents the charging data for an electric vehicle. The number of randomly generated electric vehicle charging data is the total number of such electric vehicles in the predicted area.

(4) According to the charging capacity, the initial charging capacity and the charging power, the charging time of any one of the electric vehicles is calculated.

(5) According to the initial charging time and charging time and the accumulative charging power of each electric vehicle, the load statistics of the electric vehicle connected to the power grid within one day are obtained:

$$L_i = \sum_{n=1}^N P_{n,i} \quad (1)$$

L_i indicates that the total charge power, N is the total quantity of this kind of electric vehicle; $P_{n,i}$ is the charging power of the n_{th} electric vehicle in the i_{th} minute. The charging power of the n_{th} electric vehicle in the i_{th} minute is zero if the electric vehicle is not in the charging state, that is, if a certain electric vehicle is not charged at the corresponding time, the charge power of the electric vehicle is not counted when calculating the load.

2.2 Charging characteristics of electric vehicles

Electric vehicles mainly include slow charging and fast charging modes. The charge duration is longer and the charging power is small, and the charging time is very short when the charging current is up to 150 ~ 400A and the charge current is up to 150 ~ 400A with a large current. From the point of view of charging cost and impact on power grid, slow charge cost is lower, impact on power grid is less, and battery life will not be affected. so it is the most widely used charging method. Because different types of electric vehicles adopt different charging modes, they need to be discussed separately.

2.3 Travel demand of various types of electric vehicles

The charging period of an electric vehicle is directly determined by the travel time of an electric vehicle. According to the results of the US Department of Transportation's statistics on the domestic vehicle travel in the United States, the charging time of the user's vehicle meets the normal distribution, and the probability density function is as follows:

$$g(x, \mu, \sigma) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \quad (2)$$

In the formula, μ and σ are the mean and standard deviation of the vehicle's actual charging time. For different types of cars, the corresponding μ and σ values are different.

Initial charging capacity SOC for electric vehicles, It can also be represented by probability distribution. Fitting through a large amount of data, It is found that the initial charging capacity SOC also meets the normal distribution. Based on the know-n initial charging capacity (SOC), the charging duration T of an electric vehicle can be calculated:

C_a is battery capacity; S_{SOC} is Initial charge capacity; P_r is Charging load.

$$T = \frac{C_a(1 - S_{SOC})}{P_r} \quad (3)$$

2.4 Process end

When $P_r = P_{rmax}$ Calculate the full load. Then determine the number of charging devices based on formula (5). N_F, N_S is the number of fast-charging and slow-charging piles, C_F, C_S is the rated power of fast charging pile and slow charging pile.

$$\begin{cases} N_F = \frac{P_r}{C_f} \\ N_S = \frac{P_r}{C_s} \end{cases} \quad (4)$$

N_F, N_S are the number of quick-filled and slow-filled piles, C_F, C_S is then rated power of fast charging pile and slow charging pile.

3. case analysis

3.1 Regional charging facility capacity configuration

There is no complete operating data of electric vehicles, and only the driving information samples of traditional automobiles can be used. Most of the relevant researches at home and abroad [2-5] use the National Household Travel Survey (NHTS) conducted by the US Department of Transportation as a sample of the original data set. The latest data collection, NHTS-2009, contains approximately 1 million driving records, sufficient to cover all travel characteristics of a medium-sized city single-day electric vehicle.

3.2 Load estimation without considering the difference of models

First, the following assumption is made: 90% of the initial C_{SOC} of the vehicle satisfies a uniform distribution of (0.8, 1.0), and the remaining 10% of the initial C_{SOC} of the vehicle satisfies a uniform distribution of (0.3, 0.8). When a trip may cause the C_{SOC} to be below the 20% alert value, the owner will choose to charge quickly. The charging process is unified with constant power charging, fast charging power is 60kW, slow charging is 5kW; each charging station is equipped with 6 fast charging piles.

According to the research in the [1], in a typical day, 14% of the vehicles do not travel, so 8600 single-day driving records are extracted from the original data set, and the fast charging and slow charging curves are respectively shown in Figure 1. 2.

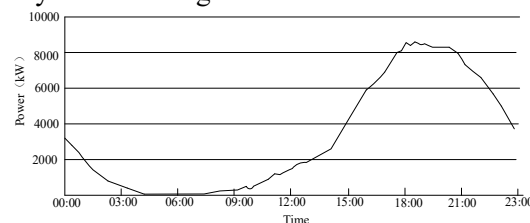


Figure 1. Typical daily slow load curve without considering vehicle differences

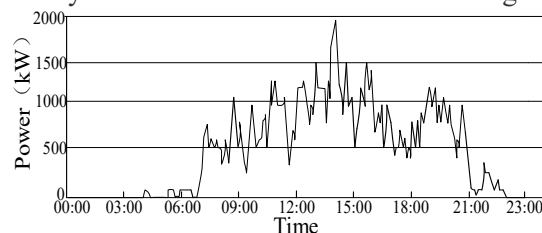


Figure 2. Typical daily quick load curve without considering vehicle differences.

It can be seen from the slow charge curve of Fig.1 that the peak charging is mainly concentrated from 16:00 to 22:00, the peak value is around 18:00, and the maximum load is about 8200 kW, which requires about 1,700 slow-filled piles. It can be seen from the fast charge curve of Fig.2 that the fast

charge has no obvious peak-to-valley characteristics. The maximum value appears near 13:00, and the load is about 1900 kW. Then about 33 sets of fast-filling piles are needed, so that the charging facility configuration scheme is obtained as Table 1 shows.

Table1 Charging setup configuration scheme

scheme	Slow charge configuration	Quick charge configuration
100% fast charge and 50% slow charge	About 850 5kW slowly filled piles	33 60kW piles need 6 charging stations
Meet 80% fast charge and 30% slow charge load	About 500 5kW slowly filled piles	20 60kW piles need 4 charging stations

Table2 Power batteries and range parameters for mainstream electric vehicles

motorcycle type	Battery type	Battery capacity/ kWh	Continuous mileage/km	Vehicle proportion/%
BYD e5 compact car	Lithium iron phosphate battery	43	305	50
BAIC E150EV small car	Lithium iron phosphate battery	25.6	150	25
EX260 small SUV	Ternary lithium battery	38.6	250	25

Table3 Charging facility configuration scheme

scheme	Slow charge configuration	Quick charge configuration
100% fast charge and 50% slow charge	About 650 5kW slowly filled piles	55 60kW piles need 11 charging stations
Meet 80% fast charge and 30% slow charge load	About 400 5kW slow filling piles	44 60kW piles need 8 charging stations

3.3 Load estimation taking into account differences in models

The above simulation calculation ignores the two factors of vehicle type difference and charging behavior uncertainty. In this section, the three mainstream electric vehicles on the market in Table 2 are selected. The proportion of the same type of traditional vehicles in the city is expected to be 50%, 25% and 25% respectively. In addition, considering that the charging behavior has greater uncertainty, it is assumed that after one-day driving, 20% of the owners choose fast charging, and the load curves of fast charging and slow charging are shown in Fig. 3 and Fig. 4.

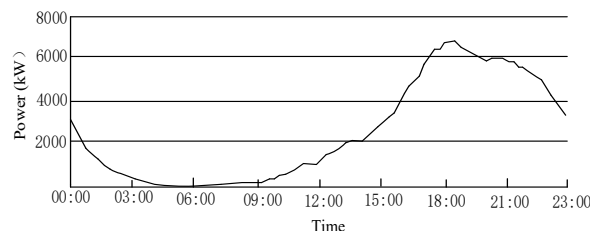


Figure 3. A typical daily slow load curve that takes into account vehicle differences and the uncertainty of charging behavior

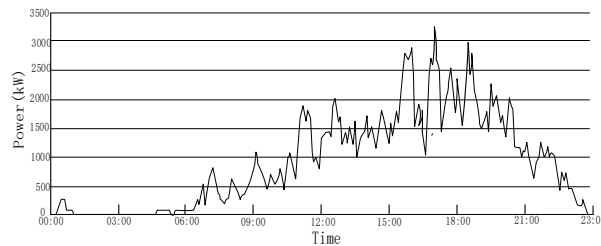


Figure 4. A typical daily fast load curve that takes into account vehicle differences and the uncertainty of charging behavior

As can be seen from the slow charge curve of Figure 3, the peak charge is mainly concentrated from 16:00 to 22:00, the peak occurs at 18:00-19:00, and the maximum load is about 6500 kW. Therefore, about 1300 slow-fill piles are needed. As can be seen from the fast charge curve of Figure 5, when the daytime trip is over, 20% of the owners choose the fast charge mode. The fast charge peak is concentrated at 15:00-19:00, and the peak value is about 3250 kW. Therefore, it needs to be fast-filled. 55 sets, according to which the charging facility configuration scheme is shown in Table 3.

4. Conclusion

In this paper, an electric vehicle load forecasting method based on user behavior is proposed. Based on the charging load modeling based on user habit simulation, the charging setting configuration of fast charging pile and slow charging pile is obtained. The electric vehicle load that took into account user behavior in the region was successfully predicted. The practical application shows that the electric vehicle load forecasting method is more accurate and objective through the electric vehicle example in a certain area. As a basis, the electric vehicle capacity allocation method can reduce the user's power consumption difficulty to a certain extent, and is beneficial to the electric vehicle's Promotional application.

Acknowledgements

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