Research on planning strategy of charging piles for electric vehicles based on markov model and charging load prediction

Hongqing Li[a,b,*], Kai Kang[a,b,1], Qianlong Feng[a,b,2], Fan Zhang[a,b,3]
[a]China Automotive Technology And Research Center Co., Ltd.; [b]China Auto Information Technology (Tianjin) Co., Ltd.

ABSTRACT

With the increasingly serious energy crisis and environmental problems, EV (Electric Vehicle) has become the development trend of automotive energy and environmental protection in the future. As an important supporting system for the development of EV, the charging infrastructure will inevitably affect the power quality of the distribution network when large-scale EV is put into operation. Therefore, this paper proposes an EV charging facility demand forecasting analysis method based on the charging load forecasting of the Markov model, and establishes a charging facility demand forecasting model based on data fusion. Finally, the research shows that the voltage optimization of the simulated Markov model is better, but the satisfaction of the operation results of the charging pile configuration scheme before the simulated Markov model is 0.78, The operation result of the charging pile comparison planning scheme smaller than the simulated Markov model is 1.58, which indicates that the charging pile utilization rate of the charging pile comparison planning scheme simulating the Markov model is higher and the customer satisfaction is better. In this paper, Markov model is used to describe the change of the state of charge of EV users' charging piles during a day's trip, and determine the real-time charging requirements of different types of EV users.

Keywords: Kolkov model; charging load prediction; electric vehicles; planning strategy of charging pile

1. INTRODUCTION

In recent years, with the continuous progress and development of science and technology, people's living standards have been generally improved, and cars, as the mainstream means of transportation, have gradually integrated into people's daily lives. Although the automobile provides convenience for people to travel to a great extent, the exhaust pollution caused by its power supply by petroleum products has become one of the main air pollution sources, and the traditional internal combustion engine locomotives have two fatal problems: energy shortage and environmental pollution. Thus, it is particularly important to synchronize the planning of distribution network and charging and replacing facilities. The planning and design of EV charging mode and charging pile location must consider the voltage quality of public power grid. At present, the urgent task of accelerating the popularization and application of EV is to further vigorously promote the construction of charging facilities, which is also an important strategic measure to promote the energy consumption revolution [1].

However, in the actual construction process, there is a huge contradiction between the low utilization rate of charging facilities and the backward status of charging facilities, mainly due to the lack of quantitative analysis on the demand forecast of charging facilities, and the construction of charging facilities is not coordinated with the development of EV [2]. The charging load is influenced by many factors, and its temporal and spatial distribution is random, so it is difficult to predict the load. Usually, considering the scale, charging mode, operation law, battery characteristics and electricity price system of EV, a load forecasting model is established.

*lihongqing@catarc.ac.cn; [1]kangkai@catarc.ac.cn; [2]fengqianlong@catarc.ac.cn; [3]m13502037247_3@163.com

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Therefore, this paper puts forward a method for forecasting and analyzing the demand of EV charging facilities based on Markov model. Starting from the present situation, on the basis of forecasting and analyzing the number of EV and charging demand, a forecasting model of charging facilities demand based on data fusion is established, which is a valuable exploration for the theory of forecasting the demand of charging facilities [3-4]. A satisfaction function considering the utilization rate of charging piles and customer waiting time is proposed to determine the number and scale of charging piles. At the same time, taking the minimum voltage offset of distribution system as the objective function, and under the constraint of satisfaction function, Markov model is used to describe the change of charging state of EV users during a day's trip, and the real-time charging requirements of different types of EV users are determined. Considering the moving characteristics of EV in the planning area, Monte Carlo method is used to predict the fast and slow charging load demand of various vehicles in different regions [5].

2. INFLUENCING FACTORS OF ELECTRIC VEHICLE CHARGING LOAD

2.1 Type of electric vehicle

As a driving force for the development of human society demand for energy in the world is increasing, especially in developing countries like China. The charging load of EV is affected by many factors, the different basic parameters of different types of EV will also affect the charging load. In addition, it is also related to the user's behavior habits, the charging mode of EV and the characteristics of battery, as well as the charging power of charging pile and charging station [6]. The electric drive control system is the core of EV. At present, there are four main types, as shown in Figure 1.

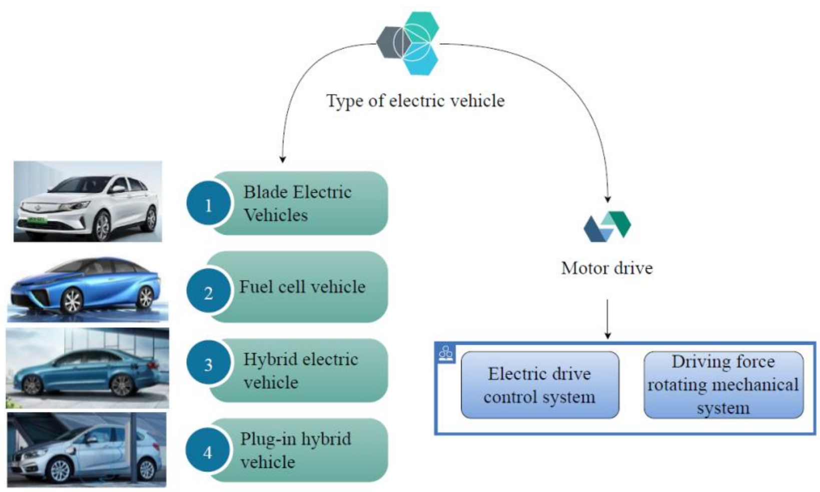

Figure 1. EV type analysis

①Pure EV

Pure EV technology is relatively simple and mature, which is the development direction of vigorously promoting in the future. However, at present, the main reasons restricting the development of pure EV are that the battery technology is not mature, the storage capacity is small, the price is expensive, and the economic scale has not yet been formed. The driving range of one-time charging is relatively short, which is only suitable for EV driving in short distance. The manufacturing technology is much less difficult. With the progress of science and technology, the performance indicators widely promoted in China are sufficient to meet the travel needs of most users, and the technology is basically mature [7-8].

② Fuel cell vehicle

Fuel cell vehicle is a kind of LI, and a single fuel cell must be assembled into a fuel battery pack in order to obtain enough power to meet the vehicle demand. From the aspects of energy utilization and environmental protection, it is by far the most energy-efficient and environmentally friendly EV, but at present, some key technologies of fuel cells need to be improved. In recent years, fuel cell technology has made a major breakthrough and been widely used at home and abroad.

③ Hybrid EV

EV, which consists of fuel-driven and electric-driven systems, usually uses traditional fuel, and at the same time, it is equipped with electric motors to improve low-speed power transmission and fuel consumption. In the space category, it solves the problems of difficult charging and short cruising range. When driving to a remote place with difficult charging, its cost is high and technical difficulty is still a difficult threshold to cross. At present, gasoline is the main hybrid vehicle in the domestic market, while diesel hybrid vehicle is the mainstream in foreign markets.

④ Plug-in hybrid electric vehicle

The engine or motor can be used as the power source alone, or both the motor and the engine can be used as the power source to drive the car to run, and it can be interconnected with the power grid to realize the two-way flow of power. It increases the capacity of power battery, and can run under pure electric condition. If it exceeds this mileage range, it needs to be transferred to hybrid drive mode.

Therefore, China's automobile energy power system must be based on sustainable development, transform as soon as possible, and move closer to green and pollution-free new energy vehicles. EV is currently recognized as the best solution for new energy vehicles. Economic development has accelerated the process of urbanization. In order to alleviate the environmental pollution caused by the rapid development of industrialization, people are still in a blue sky, and more and more electric buses have gradually replaced the original fuel vehicles.

2.2 User behavior habits

EV user behavior habits mainly refer to that when users drive their vehicles, they will choose the time of travel, when and where to supplement electric energy according to their own needs, which has a great impact on EV charging load. Good charging facilities can provide stable charging service for the battery. While ensuring the normal operation of the EV, they can also extend the service life of the battery. For EV users, convenient charging service can greatly increase the use experience of the EV [9].

For charging service operators, such factors as good economic benefits, efficient operation mode, acceptable management mode and low operation and maintenance costs should be considered. Combined with the capacity of the EV battery, the amount of power consumed by the EV in a day can be obtained. Combined with the expected charging threshold set by the user, the charging duration will be different. Due to the different driving characteristics of each type of EV, its daily driving mileage is also very different. The analysis of the behavior characteristics of various EVs in the analysis of fuel vehicles is related to the type of EV. μ_D and σ_D are the expected value and standard deviation of the function respectively. The specific parameters are shown in Table 1.

Table 1. Probability function parameters of daily mileage of each type of EV

Parameter	Type			
	Taxi	Official car	Bus	Private car
μ_D	4.5	4.6	5.1	3.7
σ_D	0.62	0.97	0.38	0.87

The initial charging time is a description of when the EV is connected to the power grid for charging. Due to the different driving habits of users and the differences of various EV functions, the initial charging time has great differences. However, generally speaking, users will supplement the electricity after the end of the current trip. In addition, the cost of urban construction land, the scale of charging and replacement facilities and the charging price of EV should be considered in the planning. Through the consideration of the overall comprehensive factors, the coordination and cooperation among the factors can make a scientific and reasonable planning and layout of the charging and replacement facilities.

3. RESEARCH ON CHARGING PILE STRATEGY OF ELECTRIC VEHICLE

3.1 Analysis of charging pile planning model

When charging EV, the power load is nonlinear, and there will be large harmonic current and surge voltage, which will affect the stability and power quality of distribution network, especially in fast charging mode. The charging pile planning under Markov model should not only meet the charging needs of EV users, but also ensure the economy of planning and construction, and also meet the corresponding distribution network operation constraints.

EV is divided into private cars, official cars, taxis, buses and other main types and their respective proportions. The battery capacity, single charging power, charging start time and their distribution functions of different types of EVS are shown in Table 2, and the distribution of their initial state of charge is a normal distribution function.

Table 2. Parameter setting of different types of EV

EV type	Battery capacity	Charging power	Proportion	Start time distribution function
Taxi	160	110	0.58	Poisson distribution
Official car	210	140	0.48	Poisson distribution
Bus	320	220	0.34	Poisson distribution
Private car	130	80	0.92	Poisson distribution

The basic idea of the Markov chain prediction method is to obtain the state transition matrix of the sequence through the original data sequence, with the goal of minimizing the total investment, operation and maintenance cost of the charging pile in the whole planning area:

$$\min = \frac{r_0(1+r_0)_\mu}{(1+r_0)n-1} \tag{1}$$

Where, $1+r_0$ is the number of quick-filled piles configured in the region, $(1+r_0)n-1$ is the unit price of quick-filled piles, and μ is the percentage of operation and maintenance costs in the investment cost. Upper and lower limit constraints of node voltage amplitude:

$$V_i^{\min} \le V_i \le V^{\max} i \cdots M \tag{2}$$

Where, V_i is the voltage amplitude of the distribution network node i, $V_i^{\min}$ and V_i^{man} are the upper and lower limits of the voltage amplitude of the node respectively, and M is the total number of nodes in the distribution network. Capacity constraint of charging pile access point:

$$P_{Cjk} \le P_{j\max} \tag{3}$$

Where, P_{Cjk} is the charging power of the regional k charging pile connected to the grid node j, and $P_{j\max}$ is the maximum injection power allowed by the grid node j.

The Markov model is used to determine whether there is a demand for charging and parking after each trip. The specific range of the residual in the actual value is obtained in the Markov model. The residual range is divided into several states, and the probability of one state to all other states is calculated. Then the state transition matrix of the residual transition is obtained. The grey prediction results are modified according to this situation, Thus, more accurate model prediction results can be obtained [10].

3.2 Voltage analysis of distribution network nodes

In the optimization scenario without charging mode, the charging load of EV is randomly connected to each node of the system. Considering the transfer characteristics of charging demand, that is, the maximum load demand of charging point can be transferred to other areas with surplus, the original constraint of ensuring the maximum charging load demand of a single area is transformed into the constraint of ensuring the total peak load demand of the whole planning area through Markov model. Therefore, the planning and layout of charging and replacing facilities should be based on the current situation of distribution network in this region to ensure that charging and replacing facilities can provide stable and sufficient electric energy.

Calculate the mileage, driving time and current state of charge of the EV passing path. If the state of charge is less than the threshold of state of charge, the EV needs to be charged nearby, and the current state of charge and the EV charging load will compare the predicted value with the actual value. When the EV charging load is randomly connected to any node of the distribution network, it will bring obvious voltage drop to the public power grid at the peak of charging, and it will increase with the increase of load permeability. The influence degree of voltage drop under the situation of local centralized node charging.

3.3 Example simulation

In view of the fact that there is little comprehensive consideration of EV more accurately, and on this basis, a scale forecasting model of charging and changing facilities is established to pave the way for its location planning. This paper takes the IEEE33 standard node system as an example, taking the minimum voltage drop of the system node as the objective function, and sets four charging piles in the calculation example, that is, there are 10 non-zero numbers in the node matrix. The operation process is shown in Figure 2.

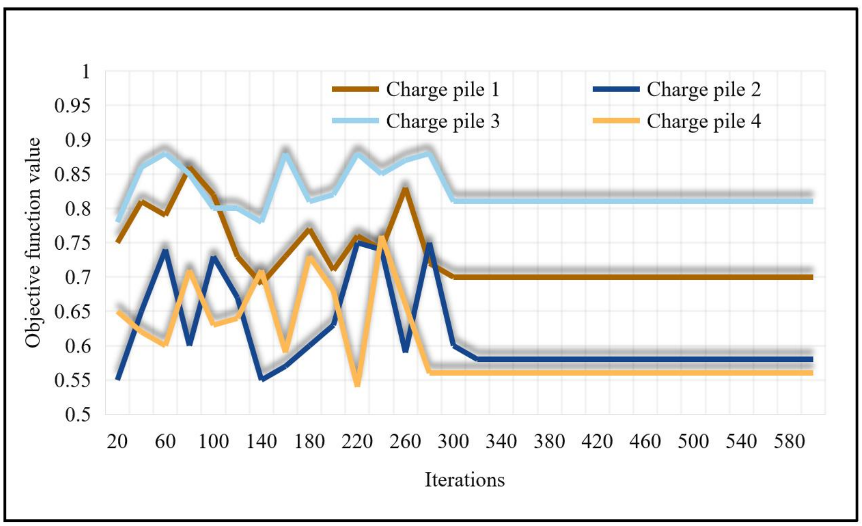

Figure 2. Operation results of charging pile configuration scheme

It can be seen from Figure 2 that among the four charging piles, the optimal solution is terminated, including 8200 internal cycles and 467 external cycles. In order to further illustrate the game relationship between the voltage offset and the satisfaction function value when planning the optimal distribution of EV charging piles, this paper sets up a group of comparison planning schemes to simulate the operation process of Markov model, as shown in Figure 3.

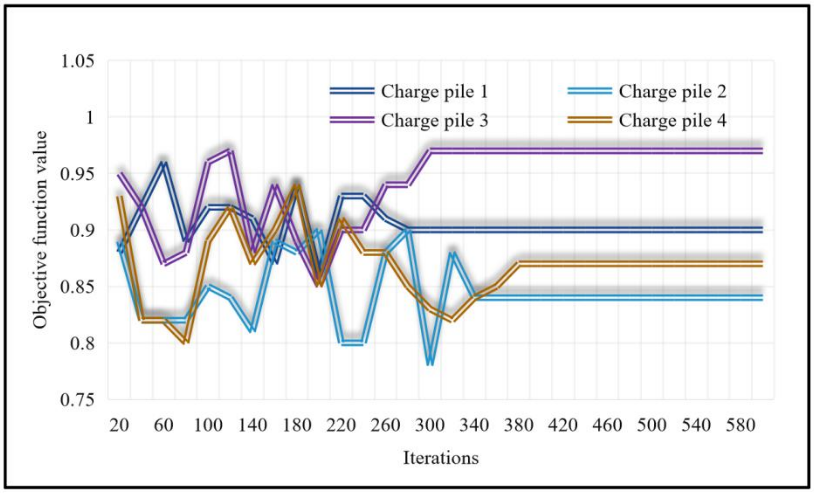

Figure 3. Operation results of charging pile compared with the planning scheme

It can be seen from Figure 3 that the voltage optimization of simulated Markov model is better; However, in order to simulate the operation result of the charging pile configuration scheme before the Markov model, the satisfaction degree is 0.78, which is less than 1.58 of the operation result of the charging pile comparison planning scheme simulating the Markov model, indicating that the charging pile utilization rate of the charging pile comparison planning scheme simulating the Markov model is higher, and the customer satisfaction is better. It can be seen that the method proposed in this paper is suitable for EV charging pile planning strategy.

4. CONCLUSIONS

In view of the two global crises of energy shortage and environmental pollution, it is very necessary to replace traditional fuel vehicles with new energy vehicles. As a typical representative of new energy vehicles, EV energy supplement depends entirely on charging and replacing facilities. Then, the optimal distribution model of charging pile location based on simulated Markov model is established with the minimum voltage drop as the goal. Aiming at the problem that the current location of charging stations only faces a single charging mode, the location model with the minimum comprehensive total social cost of conventional charging mode and fast charging mode is established. The research shows that the voltage optimization of simulated Markov model is better; However, the satisfaction of the running result of the charging pile configuration scheme before the simulation of Markov model is 0.78, which is less than the running result of the charging pile control planning scheme of the simulation of Markov model, which shows that the charging pile utilization rate of the charging pile control planning scheme of the simulation of Markov model is higher and the customer satisfaction is better.

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