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Study on Impact of Electric Vehicles Charging Models on Power Load

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Abstract. With the rapid increase in the number of electric vehicles, which will lead the power load on grid increased and have an adversely affect. This paper gives a detailed analysis of the following factors, such as scale of the electric cars, charging mode, initial charging time, initial state of charge, charging power and other factors. Monte Carlo simulation method is used to compare the two charging modes, which are conventional charging and fast charging, and MATLAB is used to model and simulate the electric vehicle charging load. The results show that compared with the conventional charging mode, fast charging mode can meet the requirements of fast charging, but also bring great load to the distribution network which will affect the reliability of power grid.

1. Introduction

With the rapid development of electric vehicle (EV) industry in China, the number of EVs increased substantially, large scale EV charging station and charging pile will be established, and the nonlinear load of power grid will be increased. User behavior of EV charging is random, therefore, it brings great challenges to the power supply and planning of the distribution network [1].

The charging model of EV is very complex, which is affected by many factors, such as the scale of EV, characteristics of power battery, charging mode and user's behavior. This paper first analyzes the development of EVs, by setting the penetration rate of EVs, the number of EVs in 2020 and 2030 is predicted; Then, the initial state of charge (SOC) of battery is set up by using the simplified model; Finally, through the establishment of charging time and charging power model, the user behavior under two charging modes is studied. The charging mode of EV is mainly divided into conventional charging mode, fast charging mode and mechanical charging mode [2]. In this paper, Monte Carlo simulation method is used to model and simulate the two charging modes of conventional charging and fast charging, and the daily load curves of the two charging modes are analyzed and compared.

2. EV ownership forecast

At present, the Chinese government has introduced a series of policies to support the development of EVs. The future development trend of EVs in China can be summarized as follows [3]: 2010~2015, EVs are mainly used in buses, official cars and taxis; 2016~2020, achieve the large-scale operation of EVs in the public transport and official car, and vigorously develop private cars; 2021~2030, increase the development of private EVs.

According to the "Development Plan For Energy-saving and New Energy Vehicles in Ten Years(2011 to 2020)", 2015 China's EV quantity will reach 500 thousand, in 2020 will reach 5 million, in 2030 is expected to rise to 400 million [4]. This paper assumes that the penetration rate of EVs is 20%, it can be speculated that in 2030 the number of EV ownership is 80 million.

According to the "Development Plan For Energy-saving and New Energy Vehicles in Ten Years(2011 to 2020)" and the annual statistics of civilian car ownership from National Bureau of Statistics [5], it can calculate that the motor vehicle in Beijing accounted for the proportion of the total [6]. This paper assumes that the proportion of private EVs is equal to the proportion of private car ownership in Beijing, as in (1).

$$\mathrm{N_{EV}} = \eta_1 \eta_2 N \tag{1}$$

N_{EV} is the private EV ownership in Beijing; N is the national EV ownership; η_1 is private EVs account for the proportion of the total EVs in Beijing, its value is 81.285%; η_2 is EVs ownership in Beijing accounted for the proportion of the total amount of EVs, its value is 2.417%; Formula (1) can be used to calculate the forecast value of private EVs in Beijing in 2015, 2020 and 2030, as shown in Table 1:

Table 1. The forecast value of Beijing's private EV in 2030, 2020 and 2015

	2015	**2020**	**2030**
National EV ownership（ten thousand）	50	500	8000
Private EV ownership in Beijing（ten thousand）	0.98	9.8	156.8

3. Characteristics of battery

EVs in Beijing are mainly used LiFePO4 battery. It has the advantages of long service life, good safety performance and low cost, and can be used as the ideal power source for EVs [7]. As the SOC is affected by the factors such as temperature and battery life cycle, it is difficult to estimate SOC.

The relationship between SOC and the current is as follows:

(1) SOC<10%. The internal resistance of battery is large, not suitable for large current charge-discharge;

(2) 10%<SOC<90%. In this stage, the battery can be charged-discharged with a large current;

(3) SOC>90%. In order to prevent the deposition of lithium and over discharge, the charging and discharging current will decrease. Because it will seriously affect the battery life when the battery is in the limit working condition, should control the battery does not work at both ends of the SOC [8].

According to the analysis in the literature [3], this paper uses 10%<SOC<90% as the data selection interval of the initial SOC. It is assumed that the initial SOC of the EV is satisfied with the normal distribution $N(0.6,0.1^2)$[8].

4. Charging mode of EV

In the "Electric vehicle conductive charge coupler", EV charging mode is divided into slow charging mode(L1), conventional charging mode(L2), fast charging mode(L3). Table 2 is the charging mode of EVs in China, the table describes the rated voltage and rated current corresponding to different charging modes.

This paper mainly studies two kinds of charging modes of EV, which are conventional charging and fast charginging, and compares the daily load curve of EV charging under these two charging modes.

Table 2. Charging mode for EVs in China

Charging mode		**Rated voltage/V**	**Rated current/A**
L1		single-phase 220	16
L2	**2-1**	single-phase 220	32
	2-2	three-phase 380	32
	2-3	three-phase 380	63
L3		600	300

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5. User Behavior
User behavior is the key factor that affects the demand of EV charging, which has the characteristics of time and space randomness and charge density. User behavior includes two factors: initial charging time and charging power.

5.1. Initial charging time
"The traffic development annual report in Beijing in 2012", pointed out that the peak time for vehicles to go to work at 7:30~8:30 am in Beijing; the peak time to get to the workplace at 8:00~9:00 am. After work, the peak time of the departure of vehicle at 17:00 ~ 18:00; the peak time arrive at home at 18:00~19:00. The initial charging peak period should be selected during the time get to the workplace and the time get to the home. This paper will analyze the data of all day, accurate to the minute, fitting out the curve of the initial charging time of EV.

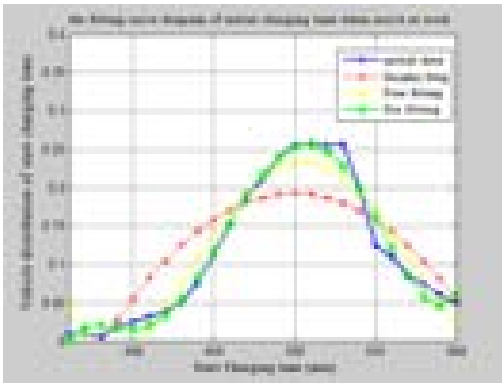


Figure 1. Fitting curve of initial charging time when arrive at workplace

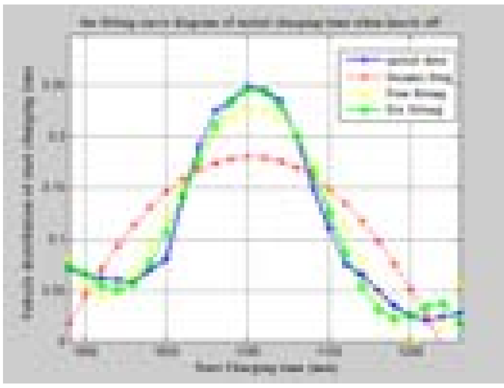


Figure 2. Fitting curve of initial charging time when knock off

According to the distribution map of arrival time of vehicle in "The traffic development annual report in Beijing in 2012", the curve fitting graph can be obtained, as shown in Fig. 1 and Fig. 2, the graph is fitted with 2 orders, 4 orders and 6 orders. From the fitting results, we can see that the 6 orders fitting is close to the original data, and can see an approximate normal distribution curve. The following is to verify whether the initial charging time of EV is in line with the normal distribution.

From Fig. 3 and Fig. 4, it can be seen that the data points of initial charging time when arrive at workplace or knock off are close to a straight line, so it can be verified that the initial charging time of EVs is approximately to normal distribution.

Based on the above analysis, the initial charging time when arrive at workplace is consistent with the normal distribution of $x_1 \sim \mathrm{N}(480, 73.5980^2)$, the initial charging time when knock off is consistent with the normal distribution of $x_2 \sim \mathrm{N}(1110, 73.5980^2)$.

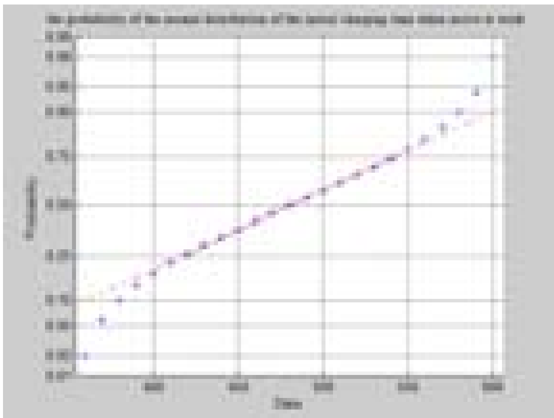


Figure 3. The probability of the normal distribution of the initial charging time when arrive at workplace

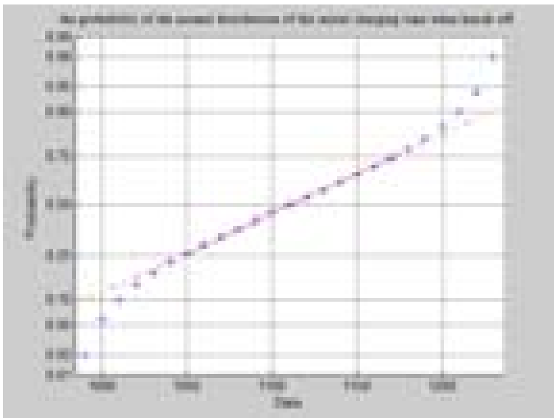


Figure 4. The probability of the normal distribution of the initial charging time when knock off

5.2. Charging power of EV

To determine the charging power of EVs, we must first understand the battery parameters. Table 3 is the parameter list of EV. The data in the battery parameter table are 5 kinds of PEVs (pure electric vehicle) and HEVs (hybrid electric vehicle).

As can be seen from the table, the current EV battery life has basically meet the daily needs of users, most EV battery capacity (C) range from 16KWh to 32KWh, the conventional charging time is about 8h in average, while the fast charging time is 0.5h. Therefore, we assume that, private cars need to charge 8 hours in the conventional charging mode, that is, the hourly charge power of 0.125C; And need to charge 0.5 hours in the fast charging mode, that is, the hourly charge power of 2C.

Table 3. The parameter list of EV

Vehicle name	Vehicle type	Mileage /km	Capacity /(kW·h)	220V Charging time/h	Fast charging /min	Release year
BMW ActiveE	PEV	160	32	5	—	2012
Roewe E50	PEV	180	18	6	30	2012
BYD E6	PEV	300	63.3	6	15	2011
Nissan Leaf	PEV	160	24	8	15-20	2010
DFPV S30	PEV	150	20	8	30	2012

From the above table can be calculated, the conventional charging power of 2~4KW, fast charging power of 32~64KW. Because the charging process of this paper is simplified as a constant power characteristic, eventually taking the conventional charging power is 3kW, and the fast charging power is 48kW.

6. The charging load model of EV

EV charging load model is based on the Monte Carlo simulation method, the initial charging time and the initial SOC of EVs are randomly selected, according to the total charge power model, the total charge power per minute can be obtained, finally the daily load curve is obtained.

6.1. The calculation model of total charging power

The total charge load curve is the sum of each EV load curve. The charging load is calculated by day, which is accurate to every minute. Formula (2) calculate the total charge power:

$$L_i = \sum_{n=1}^{N} P_{n,i}\,, i = 1,2,\cdots,1440 \tag{2}$$

Among them: L_i is the total charge power; N is the total amount of EVs; $P_{n,i}$ is the charging power.

6.2. The realization of charging load model

Monte Carlo simulation method can be used to calculate the estimated and statistical value of parameters by setting the random process and generating time series repeatedly. Fig. 5 is the flow chart of load calculation based on Monte Carlo simulation method.

The system initialization in the flow chart is to set the number of EVs; Enter the normal distribution of EVs initial SOC, that is $N(0.6,0.1^2)$ and the normal distribution of SOC at the end of charging time, that is $N(0.9,0.1^2)$; Enter the normal distribution of EV initial charging time at different time periods, that is: $N(480,73.5980^2)$ and $N(1110,73.5980^2)$.

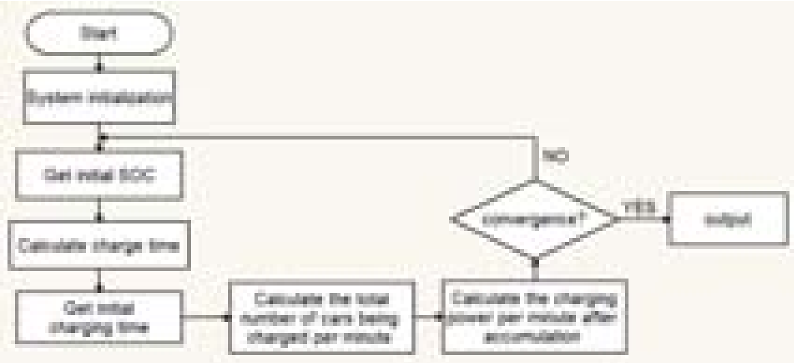
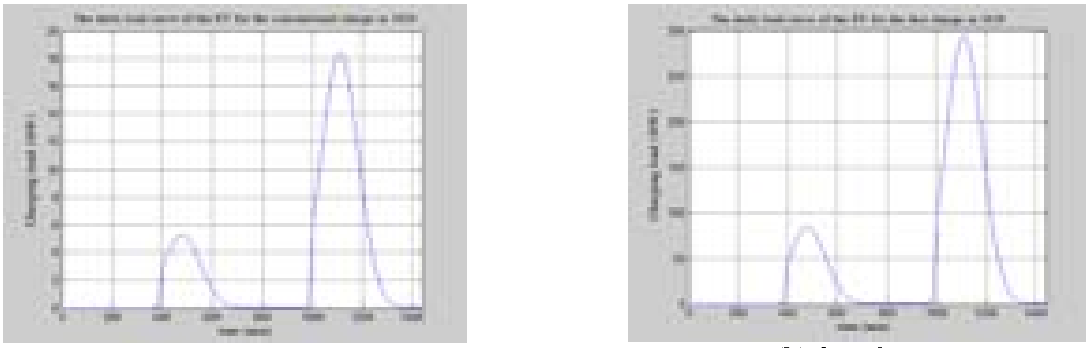


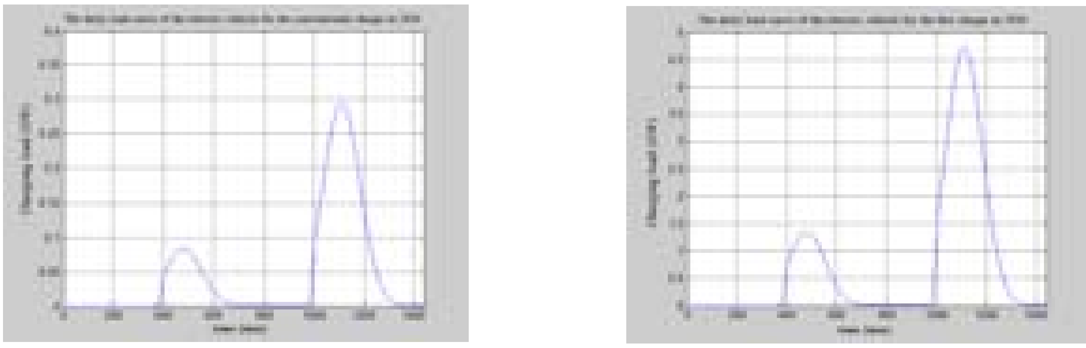
Figure 5. The flowchart of load calculation based on Monte Carlo simulation.

In this paper, the conventional charging mode and fast charging mode are selected. According to the probability distribution of the initial SOC, the probability distribution of the initial SOC and the charging end SOC is extracted, which can calculate the time required to charge. According to the probability distribution of the initial charging time, the initial charging time can be extracted, according to the charging time the number of charging EVs per minute can be obtained. Determine whether the charging power convergence, if convergence, according to the number of charging EVs, the charging load per minute can be obtained. Fig. 6 is the daily load curve of EV for the conventional charge and fast charge in 2020. Fig. 7 is the daily load curve of EV for the conventional charge and fast charge in 2030.



(a) conventional charge **(b)** fast charge

Figure 6. Daily load curve of EV for the conventional charge and fast charge in 2020



(a) conventional charge **(b)** fast charge

Figure 7. Daily load curve of EV for the conventional charge and fast charge in 2030

According Fig. 6 and Fig. 7, the peak value of the daily load curve of fast charge mode is significantly higher than that of the conventional charging mode. For the distribution network, fast charge mode will produce a higher load in a short time, will affect the normal operation of the distribution network, it will also produce "peak on peak" consequences. Table 4 shows the peak value of daily load.

Table 4. The daily load peak value of conventional charging and fast charging for EVs.

Year	conventional charging (MW)	fast charging(MW)
2020	18.4061	294.4977
2030	294.5000	4712.0000

7. Conclusion

In this paper, the influence factors of EV charging load are studied from four aspects, which are the amount of EV, the characteristics of battery, the charging mode and the user behavior, and the daily load curve of EV in Beijing in 2020 and 2030 is forecasted. Compared with the daily load curve, the fast charging mode can produce a large charging power, which can meet the requirements of EV in a short time, but it also brings a large load to distribution network. The calculation method in this paper can predict the quantity of EVs in the future, but also can be used to study the influence of future EV charging on the power grid, has certain practical value.

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