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Research on Household Energy Control Method Based on Electric Vehicle

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Abstract With the development of the automobile industry, the extensive use of automobiles is a key factor in the global energy crisis and environmental pollution, and the clean and environmentally friendly characteristics of electric vehicles have become an ideal means to deal with these two major problems. Connecting household electric vehicles to the home will not only affect the distribution network, but also adversely affect the home electricity network. Therefore, it is necessary to connect electric vehicles to household charging load for quantitative analysis, so as to design energy control methods for electric vehicles to connect to households, and minimize the adverse effects of electric vehicles connected to household power grids. First of all, this article analyzes the uncertainty of electric vehicle access to the grid. After considering the random characteristics of electric vehicle charging load, an electric vehicle charging load model is built based on Monte Carlo simulation. Secondly, according to the electric vehicle charging load power curve obtained by the above method, combined with the daily load probability model of the grid, a household electricity model is established. Finally, based on the Particle Swarm Optimization(PSO), a family energy control method is proposed, and the optimization goal is to minimize the daily load fluctuation of the family, so as to minimize the impact of electric vehicles connected to the grid.

Keywords: *electric vehicle charging, household energy control, Monte Carlo Method, PSO*

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1. Introduction

The rapid development of the automobile industry has also brought about many problems. Fuel vehicles have aggravated the consumption of non-renewable energy sources such as petroleum, and the burning of fossil fuels has also brought about air pollution [1,2]. Under the industrial development themes of low carbon, economy, green, and environmental protection, electric vehicles will play an important role in the future automobile market with their clean, environmentally friendly, energy-saving and emission-reducing characteristics. As an electric load, electric vehicles have uncertainties in the timing and spatial distribution of their charging, which will greatly increase the difficulty of controlling the power grid and lay hidden dangers for the stable operation of the power system. When a large number of electric vehicles start charging at the same time during the original load peak time period of the system, the total load of the system will greatly increase, which will not only generate new load peaks, but also cause greater load peak-to-valley differences, which will bring about the normal operation of the power distribution system. Affect, and will shorten the service life of the equipment [3]. Because the behavior of electric vehicle owners is unpredictable and the charging rules are not easy to determine, this adds difficulty to the regulation and management of power supply in the distribution network, which affects the reliability of the power system [4,5,6]. It can be seen that the charging of electric vehicles into the home will not only affect the domestic electricity network distribution network, but also adversely affect the regional distribution network [7]. It is of great significance to study the impact of private electric vehicles connected to the household electricity network for charging.

In the research of electric vehicle charging technology, Hu Zechun simulated and analyzed the random charge and discharge load curves of different types of electric vehicles, but he failed to systematically analyze the impact of electric vehicle charging and discharging behavior on the normal operation of the system [8]; Paper [9] starts from three aspects of electric vehicle charging time, daily mileage and charging power, the Monte Carlo method is used to obtain the charging load curve, but the model does not consider the user's charging behavior, and the randomness factor is not comprehensive enough. Scholars such as Md Shariful Islam proposed a variety of control strategies based on the state of charge of electric vehicle batteries to calculate the day-ahead combined probabilistic charging load of a large number of electric vehicle charging in commercial districts, and control the electric vehicle load during the peak load period of commercial districts [10].

Although there have been many studies on the charging and discharging of electric vehicles at home and abroad, the current research on the charging and discharging of electric vehicles mainly considers the impact of electric vehicles connected to the regional power grid. When an electric vehicle is connected to the home system, the daily load curve of the household will fluctuate greatly, making the user's power consumption unstable or excessive power loss. This problem needs to be solved urgently.

Therefore, based on the above research status at home and abroad and the deficiencies in the existing research, this article takes private electric vehicles as the research object based on the current status of China’s power system, and studies the construction of electric vehicle charging load curves and household daily load curves. The authors combined to obtain the family energy control model, and explored its impact on the fluctuation of family daily load. This paper intends to establish an electric vehicle charging model and a household energy control model, analyze the impact of its access on household daily load fluctuations, and study the control method based on the household’s charging and discharging of electric vehicles connected to households, so that the load fluctuations will reach The smallest. This will improve the stability of the power supply and distribution network, that is, increase the reliability of users' electricity.

2. Electric Vehicle Charging Load Model Based on Monte Carlo Method

The application form of Monte Carlo can be divided into: direct Monte Carlo simulation, indirect Monte Carlo simulation and Markov Monte Carlo method. Direct Monte Carlo simulation samples the known probability models, assumes multiple estimated values, observes and analyzes the results obtained by the simulation, and obtains the solution of the problem. This paper follows the existing charging start time and daily mileage distribution function, and uses direct Monte Carlo simulation to extract random numbers to calculate the charging load of electric vehicles within 24 hours.

At present, there is a lack of relevant driving data for electric vehicles, and the end time of the user’s daily trip is negligibly affected by the type of vehicle. The daily distance traveled by a private car is relatively fixed, and the user’s daily mileage is not comparable to the type of vehicle Because of this, this article uses traditional car data for pure electric vehicles.

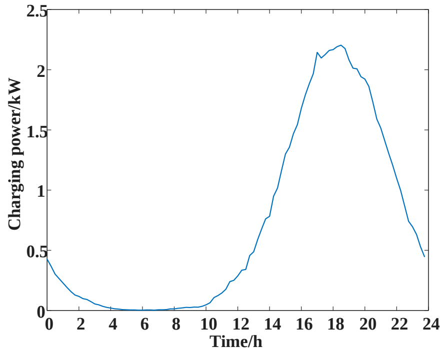

Figure 1. Electric vehicle charging load curve

Based on the Monte Carlo simulation method, the electric vehicle charging load curve within 24 hours a day is simulated [11], as shown in Figure 1.

It can be found from the figure that the electric vehicle ends its journey around 8:00 am and connects to the distribution network for charging. Since then, the charging load of electric vehicles has gradually increased. The maximum load of the day appears between 18:00 and 19:00. After 19:00 in the evening, the charging load of electric vehicles will gradually decrease. By 5:00 in the morning, the charging load is basically Is 0. The end time of the vehicle's journey is between 9:00 and 24:00, and at around 18:00, the electric vehicle ends the day's journey and goes home to charge, which is roughly the same as the charging load distribution.

The daily load peak of a household generally occurs between 18:00 and 20:00. When the electric vehicle load is directly connected to the household for charging, it is very likely to be superimposed with other load peaks in the household electricity network, resulting in new It is necessary to quantitatively explore the impact of electric vehicle charging load on the household electricity network, and lay the foundation for proposing corresponding optimization measures.

3. Household Energy Control Model Based on Electric Vehicle V2G

V2G technology considers electric vehicles as a mobile power source. When the grid load is low, the electric vehicles are charged; when the power consumption peaks, the electric vehicles are used as a power source to discharge the power grid, thus reducing the load on the grid operation.

3.1. Household Daily Load Model

Use Matlab's wblrnd function to estimate the family daily load probability model. This function uses the maximum likelihood method and is mainly analyzed based on three aspects of data:

(1) 24 hours of the day;
(2) 7 days of the week;
(3) 12 months of the year.

This forms 24*7*12=2016 random distributions. Here, the cumulative distribution variable of Weibull random distribution is:

$$F_W(x;\lambda;k)=1-e^{-(x/\lambda)^k},\ x\geq 0 \tag{1}$$

$$F_W(x;\lambda;k)=0,\ x<0 \tag{2}$$

At this time, when k=1, the Weibull distribution is similar to the exponential distribution, and when k=2 it is similar to the Rayleigh distribution. The distribution has the following mean (μ) and variance (σ2).

$$\mu=\lambda\Gamma(1+1/k) \tag{3}$$

$$\sigma^2=\lambda^2\Gamma(1+2/k)-\mu^2. \tag{4}$$

As a result, using the wblrnd function to write a program on Matlab according to the set parameters, and run the hourly household daily load probability model, the result is shown in Figure 2.

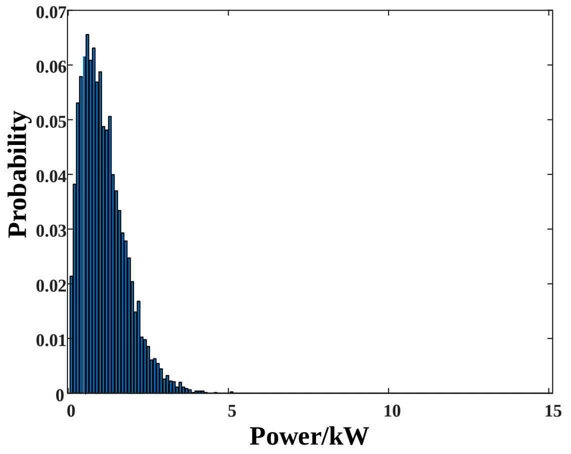

Figure 2. Household Daily Load Probability Distribution Model

3.2. Household Energy Control Model

This article intends to apply the V2G technology of electric vehicles to the home. When the daily load of the household is low, the electric vehicle is charged; when the daily load of the household is high, the electric vehicle supplies power to the household electricity network. This allows electric vehicles to directly participate in the adjustment of household daily load fluctuations. In addition, the popularity of electric vehicles is gradually increasing. If the scheme is also popularized to all electric private car users, the daily load of each user will also be optimized. When these optimized microgrids are connected to the regional power grid, they will be affected. Regional power grid regulation brings beneficial effects. Therefore, this article considers the combined treatment of electric vehicles and household daily load models, and connects electric vehicles to the household grid as a new model called the energy control model. As shown in Figure 3.

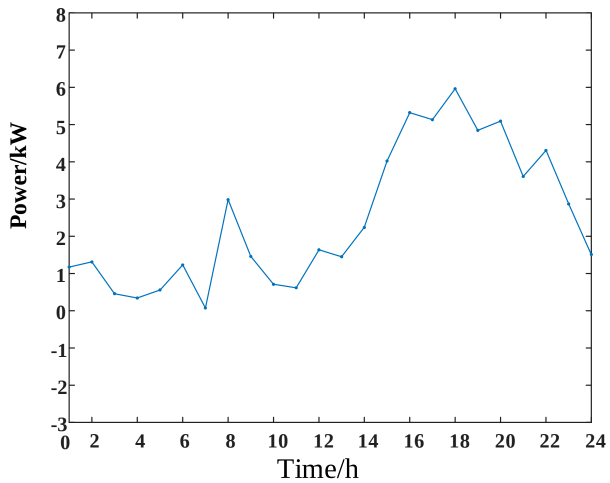

Figure 3. Load curve of family energy control model

After considering the electric vehicle V2G technology, the household energy control unit and the new power curve obtained by connecting the electric vehicle to the home. It can be seen from the figure that the new power curve is neither a simple modification of the household daily load curve, nor a derivative version of the electric vehicle charging load curve. Compared with the average household daily load curve that does not consider the electric vehicles connected to the household distribution network, the troughs and crests of this model are effectively controlled.

4. Simulation Analysis

In order to verify the effectiveness of the home energy control method proposed in this article, simulation analysis was performed in MATLAB/Simulink to verify it.

4.1. Household Energy Control Optimization Based on PSO Algorithm

Taking into account the randomness of electric vehicle charging and the randomness of household daily load, the household energy control model has a lot of room for optimization. Based on the PSO particle swarm algorithm, reasonable constraint conditions and constraint targets are set, and the optimal solution of the algorithm is obtained within this range, that is, the daily load curve with the smallest fluctuation, which will have a great significance in promoting the popularization of electric vehicles.

The family energy control model is optimized based on the particle swarm optimization algorithm. When the electric vehicle charge and discharge load and battery capacity are within the allowable range, the optimal solution that minimizes the load fluctuation of the family energy control model is found. The optimization process is shown in Figure 4:

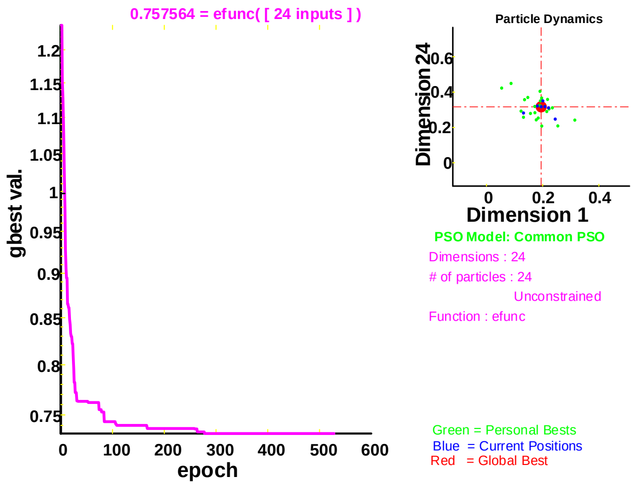

Figure 4. Optimization process of family energy control model based on particle swarm optimization

4.2. Result Analysis

Based on the particle swarm optimization algorithm process, the family energy control model connected with electric vehicles is optimized on Matlab, and then the optimal solution for load scheduling is obtained, as shown in Table 1:

Table 1. Home Energy Control Model for Electric Vehicle Access

Time/h	Power/kW	Time/h	Power/kW
1	0.304	13	0.276
2	0.463	14	0.034
3	0.374	15	-0.100
4	-0.180	16	-0.180
5	0.485	17	-0.180
6	-0.180	18	-0.180
7	0.374	19	-0.180
8	0.485	20	-0.180
9	-0.180	21	-0.180
10	0.261	22	0.011
11	0.221	23	-0.031
12	0.371	24	0.359

The data at each time point in the figure is relative to the charging and discharging power of the electric vehicle before being added to the household energy control model before optimization. When the power is positive, it means the charging power that the electric vehicle should increase at this time, and when the power is negative, it means this time. The charging power of electric vehicles should be reduced or the discharge power that should be increased as a power supply to the grid.

Table 2. Optimized family energy control model

Time/h	Power/kW	Time/h	Power/kW
1	1.620	13	1.594
2	0.920	14	1.573
3	1.508	15	1.569
4	2.592	16	2.800
5	1.384	17	1.902
6	1.725	18	3.581
7	1.645	19	4.700
8	1.380	20	2.612
9	3.203	21	2.620
10	1.611	22	1.635
11	1.630	23	1.634
12	1.610	24	1.636

According to the data in the figure and the table, it can be analyzed that after particle swarm optimization, the fluctuation of the daily load of the energy control model at various time points has converged. After particle swarm optimization of the charging and discharging behavior of electric vehicles in the family energy control model, the daily load fluctuations decreased slightly, from 1.1546 before optimization to 0.733, which was a decrease of 36.50%. It can be seen that when the load fluctuation of the family energy control model is large, due to the optimization effect of the PSO particle swarm on the charging and discharging behavior of electric vehicles, real-time adjustment is carried out, so that the daily load fluctuation of the family energy control model can be effectively controlled. Therefore, the optimization scheme has played a role in adjusting household load fluctuations.

5. Conclusions

This paper has completed the home energy control method based on electric vehicles and built related models. The main work of this paper is as follows:

(1) The relevant factors affecting the charging load characteristics of electric vehicles are studied. A calculation method of electric vehicle charging load based on Monte Carlo simulation method is proposed.

(2) Established a household daily load probability model, and combined the established electric vehicle charging load model to construct a new household electricity model.

(3) Using the PSO particle swarm algorithm, a family energy control method based on electric vehicle access is proposed. With reasonable constraints and targets, the optimal solution with the smallest load fluctuation of the family energy control model is found.

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