A New Electric Vehicle Charging-Ordered Control Model Based On Time-Divided Algorithm

Jialin He, Jiajin Qi, Zhengxian Zheng*, Yu Xu, Leijing Shan, Xingping Yan
State grid hangzhou power supply company, hangzhou, 310018.

* Corresponding author Email: dayou82@qq.com

Abstract. This paper proposed a novel plug-in electric vehicle charging-ordered based on time-sharing control algorithm, the algorithm under the condition of meet the demand of the electric car charging users, by charging stations operating income maximization as the goal, uses the monte carlo simulation method to simulate the user charge needs to transport characteristic of the electric car users conditional probability analysis, and then through the way of peak stagger, established the mathematical model in orderly electric vehicle charging stations. Research results show that the dynamic grid through time-sharing control and time-sharing electricity two kinds of incentive, orderly charging control method can significantly improve the economics of electric vehicle charging station distribution network, reduce the voltage stress of distribution network, and has high computational efficiency.

1. The Introduction
With the development of electric vehicles(EV), adopting the centralized control method to control the huge number of electric vehicle charging orderly put forward very high requirements to the computing power of the grid and electric vehicle control center[1-5]. Instead, as a relatively small amount of electric car charging, charging station can real-time acquisition electric vehicle charging information quickly[6-7], and according to the power grid real-time state, meet all of the charging needs of customers, achieve orderly charge control[8-10]. On this basis, combined with the sub-station zoning control, the coordinated charging control of regional power grid can be realized quickly and economically[11].

The purpose of this paper is to study the coordinated control strategy of orderly charging in intelligent charging stations of electric vehicles. Aim for the intelligent charging station running economic benefit maximization, with the constraint of transformer operation under load and maximally meet the requirement of electric vehicle charging user constraints, establish an ordered electric vehicle charging control optimization mode, so as to realize the coordination of charging stations in electric vehicle charging control.

2. The goal of intelligent charging-ordered
For charging stations equipped with special power distribution transformers, the conventional load is small and can be ignored. As electric vehicle charging service providers, the electric car charging stations collect payment for charging service according to the charge of electricity, and pay for electricity according to the power purchase price to the grid company, achieving profitability through the difference of the two. Set up a charging station with charging machines, whenever new EV
customers access to the number charging machine (=1,2,3,…, ), charging control system collect information of electric vehicle battery capacity, and battery charged current status (i.e., the electric car battery and battery current in proportion to the total capacity) from the electric car battery management system. In order to formulate ordered electric vehicle charging strategy, customer need to tell the charging control system of the charging stations of the electric car’s expected stay time and his expectation of the electric car battery charged condition when he leaves. On this basis, on the premise of meeting customer demand and charging station transformer’s no-loading, the maximum economic benefit of charging station can be realized through orderly charging control.

3. Intelligent charging-ordered model and control algorithm

3.1 Assumption condition

This paper assumes that the charging process is constant power charging and the changing power is \( P \), and the charging decisions obtained by this calculation can basically guarantee the charging demands of customers. According to the data of transformer historical conventional load (other than electric vehicle load), the normal load curve at 96 points on the same day can be predicted with a time interval of 15min. Use \( A_j \) as the \( j \) proportion of the power of the charging station to the EV in the transformer capacity is allowed to be calculated at the number \( ( j=1,2,3,...,96) \) period of time in 1, \( A_j \) is valued in \([0,1][11-13]\). For an EV charging station equipped with a special power distribution transformer, \( A_j =1 \). The electricity price information of the charging station on that day mainly includes the electricity price to purchase electricity from the power grid and the charging price charged to EV users, and respectively on behalf of \( C_j \) and \( P_j \) (\( j=1,2,3 \)). According to the current time and the expected time setting of all the vehicles in the station[14-15], confirm all vehicles’ maximum retention time from the current moment, the number of periods under coordinated control, the charging system change charging status once every 15 min.

3.2 Intelligent charging-ordered model

Aiming at maximum the operation economy of the intelligent charging station, the target function is as follows:

\[
\max \sum_{j=1}^{J} \sum_{n=1}^{N} C_{nj} S_{nj} P \Delta t (p_j - c_j) \tag{1}
\]

Where: \( C_{nj} \) is the control decision of the n charger at the \( j \) time period starting from the current moment, \( C_{nj} =1 \) indicates that the charger is opened and \( C_{nj} =0 \) indicates that the charging mechanism is closed; \( \Delta t \) is the length of a time period. In this paper, 15min is taken. Power distribution transformer capacity constraints are as follows:

\[
\sum_{n=1}^{N} C_{nj} S_{nj} P \leq A_j S_j \lambda, j=1,2,...,J \tag{2}
\]

Where: \( \lambda \) is the average charging power factor of the charging load. During \( j \) period of time, the charged electric vehicle's battery shall be charged at least to the final charge state \( Y_{nj,p} \) required at the beginning of charging, and at the same time it shall stop charging when full. Charging demand constraints are as follows:

\[
Y_{nj,d} B_n \leq \sum_{j=1}^{J} C_{nj} S_{nj} P \Delta t + Y_{nj,a} B_n \leq B_n \tag{3}
\]

Where: \( n=1,2,...,N \). Assume \( C \) as the charging machine on - off decision matrix formed by decision variable \( C_{nj} \). The above optimization model is a linear integer-programming model with decision variable \( C \). This paper use the optimization tool kit of CPLEX[15] to solve the problem, which is more efficient.
3.3 Algorithm procedure
This paper proposes an intelligent changing-ordered algorithm procedure as follows Fig.1

Fig.1 Intelligent changing-ordered algorithm procedure

In Fig.1, when the customer demands urgently, need charging stations provide a large number of electricity in a short time (for example, the larger $Y_{n,D}$ and $B_n$, the smaller $t_n$). There is no optimized solution to the problem. To solve this problem, after the user input $Y_{n,D}$, solved the optimal control strategy, if without solution, prompt the user system cannot meet the demand right now, and will decrease 2% to $Y_{n,D}$, solve again, until there is a solution. The optimization system tells $Y_{n,D}$ to customer after the final adjustment, if the customer is satisfied, it shall follow the optimized $Y_{n,D}$ after the adjustment. If the customer is not satisfied, we can only give up the customer. If the above problem is not solved when $Y_{n,D}$ is reduced to $Y_{n,D}$, then the charging station cannot meet any of the customer's charging needs and can only abandon the customer.
4. Simulation Results

4.1 Simulation parameters

Taking a charging station in a neighborhood as an example, the distribution transformer is equipped with conventional load and electric vehicle charging load. The capacity of the distribution transformer is 800KVA. The charging station has 80 charging piles. The curve of the proportion of residential load to the distribution transformer capacity is shown in figure 2. The maximum load is 50% of the distribution transformer capacity.

![Graph showing the proportion of resident load to distribution transformer capacity.](image)

The electricity price purchased by charging stations from the grid power adopts domestic industrial lime price [17], while the station charging tariff for electric vehicle in unified price, specific charging station electricity parameter settings are as shown in table 1. Assuming that the charging station provides charging service for 100 private electric vehicles every day, it analyzes the habit of residents to use electric vehicles in general. The charging data of the designed electric vehicles are shown in table 1.

4.2 Simulation results

The Monte Carlo method was used to simulate the charging demands of 100 cars within one day, and count the calculated results of two modes of orderly charging and disordered charging. By simulating and calculating the average return of charging stations under two conditions of orderly charging and unordered charging, the average return curve shown in figure 3 is obtained.

![Average return curve under orderly charging and unordered charging](image)

It can be seen from the average return curve that the average return remains basically unchanged after Monte Carlo calculates more than 400 times. The expected daily load curve and the conventional load curve were obtained to get the superimposed conventional load and EV charging load under the condition of orderly charging and disorderly charging, as shown in figure 4 below.
From above Fig.3 and Fig.4, the algorithm is suitable for real-time sequential charging control of electric vehicles in large-scale charging stations. By analyzing the ordered and disordered charging’s daily load curve, founding that in disordered charge mode, at times of peak load, a large number of electric vehicle charging access makes further raise to the peak load, exacerbating the peak valley difference. However, under ordered charging mode, although late peak did not rise further, but at night valley electricity period, due to the cheap power purchase price, charging stations, to obtain greater economic benefits.

5. Conclusion

This paper proposes an intelligent changing-ordered scheme and algorithm which particularly suitable for parking lots with multiple charging piles and charging monitoring systems. This scheme and model change the starting and stopping state of charging machine of charging station every 15 minutes. This time interval can be set reasonably according to the actual situation. Further research directions include the following two aspects:

(a) In order to effectively reduce the influence of ev charging on the power grid, the multi-target ordered charging control and the charging stations’ coordinated ordered charging control are adopted.(b) In the charge control model, the effect of changing the charging state on the battery life should be considered

Acknowledgments

This paper is subject by program from the State Grid Zhejiang Electric Power Corporation science and technology, No. 5211HZ16000L, Program Title: Research and Development of Intelligent EV Charging Station for Variable Integration Charging.

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