A Review of Research on Ordered Charge and Discharge of Electric Vehicles

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Abstract

In recent years, people have much paid more attention to the maintenance of environmental conditions and the rational use of fossil energy. Electric vehicles have received the attention and favor of people all over the world because of their clean and pollution-free characteristics. Reasonable control of the orderly charging and discharging of electric vehicles can not only have a positive impact on the operation of the power grid, but also bring great convenience to our daily life. Therefore, this paper reviews how to control the charging and discharging of electric vehicles in an orderly manner. The orderly charge and discharge of electric vehicles can be measured from the two dimensions of time and space. This paper gives the constraints for the vehicle owner's demand for electricity consumption, the consideration of power consumption time, and the consideration of transformer capacity. So that the optimal solution in the feasible domain can be determined, that is, the essence of the ordered charge and discharge problem. The article also introduces the use of Monte Carlo method to solve the mathematical expectation of each electric vehicle to replace the battery in a certain period of time, so as to more rationally guide the orderly charge and discharge. Finally, relevant suggestions were put forward to the relevant departments, and the future situation was prospected.

Keywords

Ordered charge and discharge, Electric vehicles, Time and space dimension, Monte Carlo method.

1. Introduction

1.1 Research Background:

With the rapid development of the economy, environmental problems have become increasingly serious. Traditional oil-fueled vehicles have caused a large amount of greenhouse gas emissions, and the shortage of fossil fuels has also become the focus of attention. As a result, technologies such as renewable energy technology and electric vehicle technology have emerged as the times require and become the frontiers and hotspots of current research.

China's electric vehicle industry has undergone a revolution from scratch, and the technology is in a state of continuous improvement. It has established a full-industry chain technology system for electric vehicles with independent intellectual property rights. By the end of 2010, a total of 25 cities across the country have joined the “Ten Cities and Thousand Vehicles” energy-saving and new energy vehicle demonstration and promotion project, and 184 models of more than 50 enterprises have entered the “Recommended Model Catalogue for Energy-saving and New Energy Vehicle Demonstration and Application Projects”. Demonstrate the operation of more than 10,000 types of electric vehicles, with a demonstration mileage of more than 200 million kilometers and a cumulative passenger load of more than 9 billion passengers. The overall level and application scale of key technologies for electric vehicles are at the forefront of the international market, and breakthroughs have been made in some areas.

The rapid development of electric vehicles and their huge development potential have been widely concerned by scholars at home and abroad, and researchers have done a lot of research work. Electric vehicles need to be connected to the grid for charging and discharging, which will have an impact on the operation of the grid. The United States first proposed V2G (Vehicle-to-Grid) technology, and proposed that its implementation is based on the stability of the grid and the support of large-scale renewable energy. Large-scale demonstration projects for large-scale charging and discharging of electric vehicles are also being carried out in Denmark. The country mainly uses electric vehicles to store wind energy, so that the two-way flow technology of electric vehicles can be fully utilized. When the wind is large, the electric vehicle is charged and the wind energy is stored; when the wind is small, the electric vehicle feeds back the electric energy to the grid, so that the electric vehicle and the wind energy are utilized efficiently, and the probability of impact on the power grid is reduced, and the reliability of the power supply is increased.

In China, research related to V2G technology is still in its infancy, and there are not many research institutions. However, in recent years, China has gained a lot of valuable experience and rich research results from the vigorous development of smart grid, which is V2G. The development of technology has laid the foundation for this. For example, at the 2010 Shanghai World Expo, China State Grid Corporation demonstrated the results of the cooperation between V2G technology and smart grid. V2G technology will certainly have a broad space for development in China because it has always been valued and developed.

1.2 Research Results Have Been

Literature 1 introduces the calculation method of charging load, which is mainly divided into two types: deterministic charging load and uncertain charging load. At the same time, it analyzes the possible impact of electric vehicles on grid stability, and points out the significance of the study of orderly charging and discharging of electric vehicles. Based on the K-means clustering model, Literature 2 clusters the charging piles from the spatial dimension and guides the users to charge during off-peak hours and discharge during peak hours, which not only relieves the operating pressure of the grid, but also achieves the goal of user economy. Literature 3 discusses charging requirements in different situations based on the Thevenin equivalent circuit model. Literature 4 established a charging and discharging simulation model and proposed a charging and discharging strategy for electric vehicles according to different situations.

2. Main Body

How to properly control the effective charging and discharging of electric vehicles is of great significance. It is not only related to our daily life, but also closely related to the normal operation of the power grid. The orderly charging strategy of electric vehicles refers to the use of practical and effective economic or technical measures to guide and control the charging of electric vehicles under the premise of meeting the charging requirements of electric vehicles, and to cut the peaks and fill the grid load curves, so that the variance of the load curve is small. It not only reduces the construction of power generation capacity, but also ensures the coordinated development of electric vehicles and the power grid. The quantitative assessment of the impact of large-scale electric vehicles on the grid and the research on charging control strategies aimed at reducing negative impacts have become a hot issue of concern. Therefore, the concept of ordered charging has emerged.

2.1 Measure Orderly Charge and Discharge from Time Dimension and Space Dimension

The order charge and discharge of electric vehicles can be measured from two aspects: time dimension and space dimension.

The time dimension mainly refers to the use of different electricity prices to guide the charging of users at different times, and can adopt methods such as peak and valley electricity prices, ladder electricity prices, district electricity prices, and dynamic electricity prices. The most widely used is the dynamic electricity price, which adjusts the price of electricity at any time according to the users and load levels connected to the grid, thus achieving the purpose of orderly charging and discharging.

The spatial dimension mainly refers to the reasonable arrangement of the location of the charging pile to guide the user to order charging and discharging. The most common method is to use K-means clustering algorithm to divide the charging pile into different classes according to the geometric distance from each charging pile to the cluster center, and accordingly, the user can select the charging location reasonably.

The orderly charge and discharge of electric vehicles is essentially a problem of solving the optimal solution in the feasible domain of the constructed objective function. How to construct the objective function and constraints becomes a very important problem. Some common constraints are as follows:

1. The owner's demand for electricity

$$SOC_{end} \geq SOC_{start}$$

SOC indicates the remaining power of the electric car. This formula indicates that the electric car's electric quantity is greater than or equal to the electric quantity before charging. At the same time, it should also take into account the user's demand for power consumption, that is, the power consumption should be greater than or equal to the user's power demand.

2. Consideration of charging time

$$0 \leq T_{start,t} \leq T_{end,t} \leq 24$$

The time after charging is completed should be later than or equal to the time before charging, and the time should be within 0-24 hours, in line with daily logic.

3. Consideration of transformer capacity

$$P \geq L_{before} + \sum P_{charge}$$

After the electric vehicle is connected to the grid for charging, its sum with the previous load should not exceed the capacity limit of the transformer.

4. User's expenses

The cost of the user when adopting the orderly charge and discharge strategy should be less than the expenditure when the relevant strategy is not adopted, and the user expenditure can also be considered as the objective function.

5. The effect of the number of times of charging

Excessive number of times of charging will affect the life of the battery. During the solution process, the number of times of charging should be minimized.

6. Node voltage limit

$$U_{\min} \leq U_{\alpha} \leq U_{\max}$$

U_{α} is the voltage of the node α, which should satisfy the constraints of the node voltage. When a large number of electric vehicles are connected to the grid, the node voltage will decrease, and care should be taken not to exceed the constraints.

2.2 The Application of Monte Carlo Method

Monte Carlo method is a stochastic simulation method based on probability and statistics. It can calculate the probability that an electric vehicle will replace the battery every time in the day, that is, the expectation of power exchange, and then integrate the total number of electric vehicles in a certain city, we can obtain the number of batteries change per time period.

The detailed steps are as follows:

1. Set a certain number of sample totals, assign values to these samples according to the following formula, and the value of each sample represents the total distance traveled by a user.

$$f_d(s)=\frac{1}{s\sigma_d\sqrt{2\pi}}\exp\left[-\frac{(\ln s-\mu_d)^2}{2{\sigma_d}^2}\right]$$

s is the user's driving distance.

2. Set the initial time of the electric car battery so that the power is in one-to-one correspondence with the users in the sample.

3. Find the number of users who need to replace the battery at each time, according to the following formula.

$$\begin{cases} s_i=s_0\sum_{t=t_0}^{t_1} f_s(t) & 0\le t_0\le t_1\le 24 \\ s_i=s_0\left[\sum_{t=t_0}^{24} f_s(t)+\sum_{t=0}^{t_1} f_s(t)\right] & 0\le t_1\le t_0\le 24 \end{cases}$$

$$\begin{cases} s_i=\frac{100(Q_0-kQ_e)}{W_{100}} & 0\le Q_0-kQ_e \\ s_i=0 & Q_0-kQ_e\le 0 \end{cases}$$

4. By dividing the number of samples in each time period by the total sample size, you get the expectation that a user will replace the battery every time of day.

3. Conclusions and Prospects

With the increasing emphasis on electric vehicles by relevant departments and governments and the introduction of relevant support policies, the popularity of electric vehicles is getting higher and higher, and the access of a large number of electric vehicles to the power grid has a great impact on the power system. Through analysis, we can find that controlling the orderly charge and discharge of electric vehicles is of great significance. A reasonable charge and discharge strategy can reduce the burden of grid operation, avoid overload operation of the grid, avoid causing unnecessary losses and damage, and reduce grid operation as well as the cost of power grid's operation. When formulating the charging and discharging strategy for electric vehicles, you should pay attention to:

(1) All aspects of control should be considered in the development of electricity prices.

(2) It is possible to consider the development of convenient remote control, such as connecting the mobile terminal to the charging setting, and managing the charging status through the mobile phone, thereby improving efficiency and convenience.

(3) Improve the relevant economic return incentive mechanism, so that users can actively register as dispatchers of dispatched electric vehicles to join V2G systems, thereby achieving relevant control and improving economic benefits.

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