Analysis of the impact of various charging modes on grid connection of electric vehicles

Zeheng Zhang\textsuperscript{1}, Weihua Li\textsuperscript{*}, Youhong Ran\textsuperscript{3} and Dianxiang Liu\textsuperscript{4}

\textsuperscript{1}School of international energy, Jinan University, Baotou, Inner Mongolia, 014100, China
\textsuperscript{*}Research Institute of Rail Transit, Jinan University, Longyan, Fujian, 364000, China
\textsuperscript{3}School of international energy, Jinan University, Zunyi, Guizhou, 563000, China
\textsuperscript{4}School of international energy, Jinan University, Zhanjiang, Guangdong, 524000, China

\textsuperscript{*}Corresponding author’s e-mail: liweihua@jnu.edu.cn

Abstract. In recent years, as a new type of green energy, electric vehicles have developed rapidly. However, the charging behavior of electric vehicles is uncertain in time and season. A large number of electric vehicles connect the load with the power grid through different charging methods, which leads to the load redistribution of the power grid. Therefore, the research on the impact of load on distribution network under different conditions can give full play to the role of electric vehicles in peak load regulation and valley filling of power grid, which is of great significance to adjust charging behavior and improve power supply reliability of power grid.

Firstly, according to the factors that affect the charging load of electric vehicles, the charger models under different charging modes and IEEE-14 node distribution network models are established. In addition, considering the daily living habits of the citizens, this paper proposes two normal distribution models to study the load distribution law of electric vehicles connected with the distribution network in different periods, and draw a one-day load curve. The peak load caused by people's charging behavior in one day is explained and analyzed. Finally, the effects of different seasons on charging behavior and charging efficiency are simulated, and the load curves of different seasons are drawn, and the results are analyzed comprehensively.

1. Introduction

1.1. Research background

With the continuous consumption of energy, more and more countries are promoting the development of new energy. As a green environmental protection vehicle in the 21st century, the market prospect of electric vehicles is gradually clear\cite{1}.

However, the access of a large number of electric vehicles brings new challenges to the security and economic operation of the power system. Therefore, the growth of electric vehicles has also brought many problems to the distribution network: due to the similar work and rest time of users, the aggregation charging of electric vehicles may lead to the load tension in local areas; and in the charging process, due to the characteristics of the existing charging rectifier device, when there is a
random variable load, it will bring harmonic interference that is difficult to control to the power grid[2].

Based on the investigation of the load data of Guangzhou and Foshan, this paper analyzes the impact of different access points of electric vehicles into the power grid in different periods from the perspective of large-scale electric vehicle chargers connected to the distribution network, and puts forward feasible charging strategies according to the simulation results, which provides a reference for the construction of distribution network after the large-scale popularization of electric vehicles in the future significance.

1.2. Brief introduction to charging characteristics of electric vehicles

1.2.1. Different types of electric vehicles. Different types of electric vehicles have different charging methods. Hybrid electric vehicle (HEV) is a kind of common hydrogen fuel cell, which continuously generates electric energy through chemical reaction, so it does not participate in distribution network analysis. Pure electric vehicle (BEV) and plug-in hybrid electric vehicle (PHEV) have the characteristics of less energy storage and large power battery capacity respectively, so they have less impact on the distribution. Hybrid electric vehicles (HEV) have two drive systems, fuel and electricity. Its operation can improve the load distribution of distribution network to a certain extent.

1.2.2. Different charging devices. According to the development status of electric vehicles, charging equipment can be divided into three categories: 380V three-phase AC charger is generally used for large and medium-sized chargers in charging stations and parking lots; single-phase AC charger or single-phase / three-phase AC charger is generally used for small household chargers with power of 3 ~ 5kW and charging time of 5 ~ 10h[4].

1.2.3. Different charging methods. At present, a variety of charging station modes are proposed, mainly in the following ways[5]: the traditional charging mode is constant voltage and constant current charging mode, the charging time is 5-8h, even 10-20h, the fast charging time is 10-30min, and the charging current is 150-400a, which is commonly used in large capacity charging stations. In addition to the above methods, there are battery pack replacement, wireless charging, mobile charging and other methods, which have little impact on the distribution network. Therefore, they are not considered in the design.

2. Grid connected modeling of electric vehicle

This paper uses Matlab / Simulink to build the charger and distribution network model. The battery data of electric vehicle is the battery parameters of BYD E6 electric vehicle. The distribution network adopts the standard IEEE-14 node standard test data.

2.1. Charger grid connection modeling

After modeling with Simulink, three kinds of charger models including wired direct charger, wireless high-frequency high-speed charger and battery switching station are completed, and they are integrated into the power grid.

As shown in Figure 1, the grid connected model of charger is established. The power supply adopts 10kV bus power supply. The system supplies power to the storage battery after 10 / 0.4kV distribution transformer step-down and a series of operation. There are 720kW wired chargers, 2 50KW battery switching station chargers and 1 4.8KW wireless charger.
According to the model established in figure 1, the connection of 5 and 10 electric vehicle chargers is discussed respectively, and the simulation results are shown in figure 2.

2.2. Distribution network system modeling

In this paper, a typical 14 node distribution network recommended by IEEE is adopted. The total capacity of distribution transformer is 3.949KWh and the total load is 3.325KWh. The structure diagram is shown in Figure 3. In this paper, the distribution network model is established by using Simpower systems toolbox and node data.
3. Influence of electric vehicles connected to power distribution network at different times or seasons

3.1. Influence of electric vehicles connected to power distribution network at different times

Due to the different access time of electric vehicles to the distribution network, the impact on the load curve is also different. In this paper, the daily load data of Guangdong Province are collected as shown in table 1.

| time interval | Load / p.u | time interval | Load / p.u | time interval | Load / p.u | time interval | Load / p.u |
|---------------|------------|---------------|------------|---------------|------------|---------------|------------|
| 0; 00         | 1.746      | 12; 00       | 2.004      | 6; 00         | 1.355      | 18; 00        | 2.518      |
| 1; 00         | 1.433      | 13; 00       | 1.629      | 7; 00         | 1.161      | 19; 00        | 2.308      |
| 2; 00         | 1.248      | 14; 00       | 2.166      | 8; 00         | 1.737      | 20; 00        | 2.308      |
| 3; 00         | 1.300      | 15; 00       | 2.619      | 9; 00         | 2.386      | 21; 00        | 2.315      |
| 4; 00         | 1.277      | 16; 00       | 2.441      | 10; 00        | 2.431      | 22; 00        | 2.137      |
| 5; 00         | 1.355      | 17; 00       | 2.454      | 11; 00        | 2.681      | 23; 00        | 1.995      |

According to the charging habits of urban car owners, the effects of electric vehicles with 40% penetration rate on the load curve were simulated by charging for 6 hours at 0:00, 6:00, 12:00 and 18:00, respectively. As can be seen from Figure 4, when the electric vehicle is connected at 0:00, the peak valley difference remains unchanged. From 0:00 to 6:00, the peak valley difference decreases and the load curve is improved. When electric vehicles are connected to the grid at 6:00, 12:00 and 18:00, the maximum load is more than 55%, forming a new peak load and expanding the peak valley difference of system load.

To sum up, when the charging behavior of electric vehicle users is concentrated at the low point of the load curve, the peak valley difference of power can be reduced, and the number of generator exits can be reduced. And its charging behavior is concentrated in peak load period, which will increase the difficulty of power generation and distribution. Combined with the characteristics of literature and load data, we can put forward corresponding suggestions to electric power enterprises: give certain discount or discount to users of electric vehicles charging at night, and realize mutual benefit and win-win situation through communication with power plants[6].
3.2. Charging load of electric vehicles with different seasons

In this paper, Guangzhou and Foshan, two mature cities of EV charging and discharging, are taken as the research objects. 8000 buses and 500000 private cars will be connected to the power grid as chargers. Simulation is carried out in different seasons to analyze the impact of charging behavior on distribution network load. According to the characteristics of urban public transport, the following assumptions are put forward:

1) It is assumed that the running time of pure electric bus is from 8:00 to 18:00, during which the bus can unload the battery at any time. It assumes that the power station operates 24 hours a day and can charge the replaced batteries all day;

2) Assuming that the travel time of private cars in daytime obeys normal distribution, the expected values are 8:30 and 17:30 respectively, and the mean square error is 30. The time to arrive at the parking lot in the evening is the same, the expected value is 19:00, and the mean square error is 30 minutes.

Relevant parameters of pure electric bus and private car are shown in Table 2. Simulation is carried out according to Monte Carlo algorithm, and charging load in different seasons is shown in Figure 5.

Table 2. Technical parameters of pure electric bus and private car.

|                      | Battery capacity (KWh) | Energy consumption (kWh / km) | Charging power (kw) |
|----------------------|------------------------|------------------------------|---------------------|
| Pure electric bus    | 52                     | 0.65                         | 13                  |
| Private car          | 21.6                   | 0.139                        | 3.6                 |

We conclude that due to the weather in summer, residents use a large number of household cooling appliances such as air conditioners and electric fans, resulting in the peak load in the afternoon, while the peak load in winter is in the evening. When the scale of electric vehicles is large (500000 private cars), the peak load period in summer will be moved to the evening, while in winter there will be "peak to peak", which expands the peak valley difference and increases the burden of the power grid.

As far as we know, the impact of charging behavior in different seasons on the load of the same city is different, and the peak load is mainly manifested in the noon in summer and the evening in winter. The load of different cities is also different, which is related to car ownership and population density.

4. Conclusion

Through the modeling of charging and grid connection, and the construction of 14 node distribution network, a set of simulation model of electric vehicle access to the distribution network is established.
It provides a basic model for the grid connected analysis of different charging modes of electric vehicles in the future. In addition, this paper simulates the situation that the charger is connected to the power grid at different times and in different seasons.

The load of electric vehicles is different when they are connected to the distribution network in different time periods. Therefore, it is necessary to improve the adverse effects result from electric vehicles accessing through the guidance of policies and electricity prices of power companies, so as to give full play to the role of "peak load cutting and valley filling".

Different seasons not only have certain effects on people's charging behavior, but also have different effects on charging performance. Therefore, in different seasons, we need to formulate different policies and consider the access proportion of different charging methods, so as to make more effective use of electric energy in different seasons.

Acknowledgments
Special thanks to Guangdong Province of China "climbing plan" science and technology innovation strategic funds for the financial support of this article.

References
[1] Yang XL. (2007) Development trend and Prospect of electric vehicle technology [J]. Automotive technology, (6): 10-13.
[2] Gao CW, Zhang L. (2011) Overview of the impact of electric vehicle charging on power grid [J]. Power grid technology, (02): 127-131.
[3] Li XH. (2005) Introduction to electric vehicles [M]. Beijing University of Technology Press, Beijing.
[4] Chen WW. (2008) Automotive body electronics and control technology [M]. China Machine Press, Beijing.
[5] Liu Q. (2011) Analysis on the influence of charging mode of electric vehicle and charging station on power quality of power grid [J]. China high tech enterprise, 2011:43-46.
[6] Yang YB, Yan QG, Wang D, Yang B, Gao H (2016) Intelligent power consumption modeling and optimization simulation analysis for residential users [J]. Power system automation, 40 (03): 46-51.