The Impact from Electricity Vehicle on City Electricity Grid

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Abstract: Nowadays, the problem of environmental pollution and resource shortage is becoming more and more obvious. Electric vehicles will replace fuel trucks with environmental protection and efficiency. However, as a newly developed grid load, charging will have an impact on the power quality and the economy of the distribution network. Based on this, we first study the charging mode of existing electric vehicles, analyze the positive and negative effects of electric vehicles on the urban distribution network, and finally carry out an example simulation with East China Power Grid to verify some of the functions of electric vehicles connected to the grid.

1. Introduction

Electric Vehicle EV is a new energy vehicle that uses electric motors instead of fuel engines [1]. It is environmentally friendly and efficient. Conventional fuel vehicles use petroleum as an energy source, which not only brings the problem of shortage of resources, but also emits pollutants such as carbon monoxide, nitrogen oxides and soot particles during the driving process to cause air pollution [2]. In response to resource and environmental issues, countries are vigorously promoting electric vehicle insurance [3].

Under the continuous promotion of policies, the use rate of electric vehicles in China is catching up with other countries [4]. As of 2018, 300,000 public charging infrastructures have been built and are expected to increase by 115,000 by the end of 2019. The number of electric vehicles is gradually increasing [5]. If the vehicle owner's charging habits are not constrained and controlled, the charging demand response curve is basically consistent with the basic load demand of the grid system, and the phenomenon of peak peaking will occur on the basis of the original load [6]. The increase will cause the voltage deviation of the distribution network. When the deviation value does not meet the national standard, it will directly affect the normal power consumption of the user [7].

In the future development, the number of private cars has an absolute advantage in the total number of cars [8]. Therefore, studying the voltage deviation caused by the private car accessing the low-voltage distribution network of the community is a hot spot for scholars at home and abroad. Some scholars have modeled a low-voltage distribution network in Bosnia in the PSAT toolbox of Matlab. There are two voltage levels in the model, and the effects of charging on the network under different permeability are analyzed [9]. Simulation results: when the permeability When set to 12%, the voltage deviation begins to exceed 10%; when the permeability is set to 50%, the voltage deviation is as high as 14%, it is not difficult to conclude that as the permeability increases, the voltage deviation increases [10].

2. Electric Vehicle Charging Load Characteristics

2.1. Regular charging mode

Conventional charging: refers to the charging method of the battery with a small current (0.1C-0.3C), and the charging time is usually 5-8 hours. Advantages: low cost, small size can realize on-board, free choice of venue; if the charging period is arranged in the base load, on the one hand, electric vehicle users can reduce the charging cost, on the other hand, the system peak-to-valley difference will also decrease. Disadvantages: Long charging time, there are many electric vehicles charging at the same time, so the scale of construction is large. Figure 1 shows the conventional charging method.

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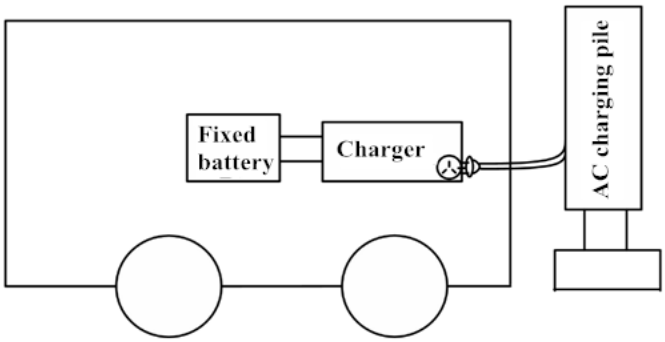

Fig.1. Conventional charging mode

2.2. Fast charging mode

Fast charging (high power charging): refers to the method of charging the battery with a large current, the charging time is usually 30-120min. Advantages: The length of charging is short, the battery can be fully charged, and the efficiency of the vehicle is improved; the construction scale of the fast charging station does not need to be as large as that of a conventional charging station. Disadvantages: It is necessary to build a charging pile by special lines. This method is costly and can only be charged to a specific place, which is relatively limited. The current is large when charging, the technical requirements for battery and charging are high, and the high current is easy to cause the battery. Damage, service life will be affected.

2.3. Replace the battery mode

Replacing the battery means replacing the battery with insufficient power directly with the fully charged battery to achieve the purpose of charging. The time required is about 10-15 minutes. Due to the heavy weight of the battery, it is necessary to arrange staff and special equipment. Advantages: The replacement speed is fast, the waiting time of the vehicle owner is reduced, the use efficiency of the vehicle is improved; the charging time of the replaced battery is arranged at a low night, which saves the running cost of the vehicle; solves the problems of long charging time and short cruising range. The battery can be uniformly maintained and managed, which can greatly improve the battery life. Disadvantages: There is a need to have uniform installation standards and interface standards to regulate automobile manufacturers, and it is difficult to implement them.

2.4. Wireless charging mode

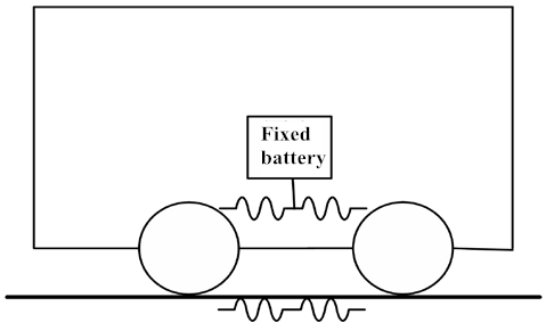

Fig.2. Wireless charging modes

The essence of wireless charging is the use of alternating electric fields and electromagnetic induction principles to enable the transmission of electrical energy. Install the coil under the car and on the ground to charge when the car is parked in the proper position. Comparing the above three charging modes, no wires and charging plugs are required and the entire charging process can be fully automated. Figure 2 shows the wireless charging mode.

3. The Impact of Electric Vehicles on Urban Distribution Networks

3.1. The positive impact of electric vehicles on urban distribution networks

Compared with pumped-storage hydropower stations, electric vehicles not only have the flexibility of peak shaving and frequency modulation, but also avoid the strict requirements of hydropower stations for site selection, and the conversion efficiency is high. In addition, the power storage technology can achieve sustainable development of the power grid, solve the contradiction between power supply and demand imbalances, and improve the reliability of power supply. With the application of PWM technology in the field of electric vehicles, it is possible to flexibly change the role of an electric vehicle as a load or distributed power source by controlling the PWM drive signal. At the peak of power consumption, the energy stored in the battery of the electric vehicle is fed back to the power grid; when the load is low, the battery is charged, which is equivalent to pumping the storage power plant to pump water from a low water level to a high water level to store electrical energy.

The Power System Dispatching Management Regulations stipulate that the frequency deviation cannot exceed 0.5 Hz and requires a response within 10 s. Because hydropower plants are quicker and more flexible than coal-fired power plants, at present, China has basically adopted pumped-storage power stations to undertake FM tasks. However, the construction of pumped storage power stations has high requirements on the terrain, and the investment is generally large. As electric vehicle charging and discharging technology matures and the degree of automation is higher, electric vehicles may replace certain hydropower stations to undertake certain FM services in the future.

In order for the power system to operate safely and reliably, it is necessary to have a certain spare capacity to meet the system load fluctuation and the capacity requirements for accident repair. The spare capacity is divided into a spin reserve and a cold spare. Rotating standby, also known as hot standby, refers to the part that has been connected to the grid but only has a partial load and can increase the output at any time. At present, China's rotary standby is generally undertaken by the thermal power unit, which not only consumes a large amount of fuel, but also the thermal power unit is in a low-efficiency operation state for a long time. If the electric vehicle is partially rotated, it can liberate a large number of thermal power units and improve power generation efficiency. Electric vehicles can be integrated with intermittent power sources such as solar energy and wind energy to achieve comprehensive dispatching, and improve the ability of power systems to accept renewable energy. Power system startup is generally undertaken by pumped-storage hydropower stations, but if black-start is achieved by electric vehicles, the system will recover faster.

3.2. The negative impact of electric vehicles on urban distribution networks

The disordered charging of a large number of electric vehicles can significantly increase the distribution system network loss and deteriorate the power quality. Electric car is a non-Linear load, its input will bring a lot of harmonics to the grid. Harmonic currents distort the current waveform and reduce the power factor. Harmonic currents create a circulating current in the delta-connected transformer windings and increase the eddy current and hysteresis losses of the core. Harmonic current increases the impedance of the transmission line and has a skin effect, resulting in increased transmission line losses. Harmonics can cause grid resonances, resulting in resonant overvoltages or resonant overcorrects. The influence of harmonics on the relay protection and automatic device based on the negative sequence (fundamental) quantity in the power system is very serious. This is because the protection device set by the negative sequence (fundamental wave) is small in setting value and high in sensitivity. In addition, harmonics can also cause electromagnetic interference.

3.3. Economic and social value of electric vehicles connected to the power grid

For grid operators, electric vehicles as power supplies to the grid and provide frequency and spin backup services can reduce the spare capacity of grid operators, reduce investment requirements for new power plants and infrastructure, and improve the reliability of power systems. Sexuality, by

increasing the storage of electrical energy to allow renewable energy to increase percentages, and the price of its services is more competitive. Therefore, the grid operators benefit. For electric vehicle owners, electric vehicles are charged during the nighttime low electricity price period and used as a load; they are discharged during the peak daytime electricity price and used as a power source. In this way, the owner of the electric vehicle can obtain the cost formed by the price difference of the electricity price, partially compensate the initial investment of the electric vehicle, and reduce the cost of maintaining the electric vehicle. The impact on the natural environment, the use of electric vehicles can reduce the amount of gasoline used, solve energy shortages, reduce greenhouse gas emissions, partially replace thermal power plants, and can be integrated with renewable energy. It is well known that carbon monoxide, hydrocarbons, nitrogen oxides, lead compounds and particulate matter in the exhaust gas of internal combustion engines are prone to acid rain mist and photochemical smog. Electric vehicles have no exhaust gas generated by internal combustion engines, and their noise is smaller than that of internal combustion engines. Therefore, electric vehicles can be called “zero emission pollution cars”

4. Impact of Electric Vehicles on the Power Grid

4.1. Impact on daily operation of the grid (load curve)

After the electric vehicle is connected to the power grid, it will provide more available power to the dispatcher, change the daily load curve of the access point, make the peak-to-valley difference smaller, and play a certain peak-filling effect. For the five substations in East China Power Grid, the electric vehicles were connected in the summer high-speed operation mode in 2010 to study the effect of the access. Its access mode is shown in Table 1.

Table 1 Electric vehicle parameters for accessing substations

Parameter	Numerical Value
Charge and discharge power / vehicle • kW	-1
30	Total number of electric vehicles / vehicle 15 000
Number of electric vehicles / vehicles • Station	-1
3000	Participate in V2G ratio /% 20
The discharge rate is 0. 8	Number of vehicles discharged / vehicle 480
Maximum discharge power / MW 14. 4	Discharge time period 10:00 ~ 14:00
Charging rate is 0. 2	Number of vehicles charged / vehicle 600
Charging maximum power / MW 18	Charging time 23:00 ~ 7:00
Charge and discharge power / vehicle • kW	-1
30	Total number of electric vehicles / vehicle 15 000
Number of electric vehicles / vehicles • Station	-1
3000	Participate in V2G ratio /% 20

Through the research and analysis of the effects after the access of each substation, it is found that the electric car can play a certain peak-filling effect after access. The size of the specific effect is determined by the substation load power and load characteristics. If the daily load curve is a typical load curve with peaks, valleys, and smooth changes, the effect after access is obvious, and the peak-to-valley difference can be reduced by up to 34%.

4.2. Impact on grid planning

The original grid planning did not take into account the electric vehicle factor, but the electric steam that exists as a load and distributed power source. The car will inevitably change the structure of the power distribution system and have a great impact on the power grid planning. The power distribution system will change from a radial network to a network of power and users, and its control and management will become more complicated. The planning and operation of the distribution network will also be completely changed. Among them, reactive power compensation, voltage control, and substation capacity planning all need to consider the impact of electric vehicles.

In particular, an electric vehicle that exists as a load at night will cause a large change in nighttime power. Taking the East China Power Grid as the research object, on the basis of the grid planning grid structure, the power flow calculations after accessing the electric vehicles in 2015, 2016, 2017 and 2018 are respectively carried out, so as to analyze the change rate of the active power after the access, and the site The effect of voltage. The load flow of one of the stations in the high operation mode in the summer of 2015 to 2018 is calculated. After the access, the load and power change rate of the station is as shown in the following figure.

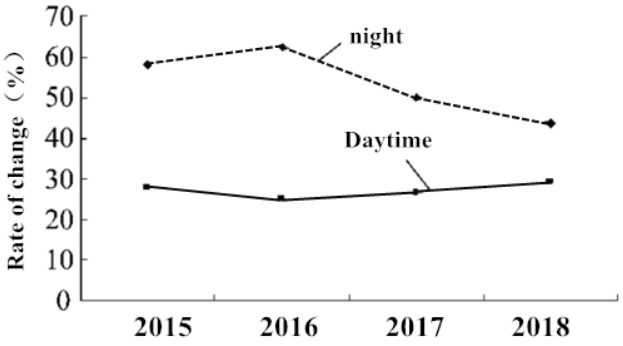

Fig.3. Site load active rate of change

The study found that the electric vehicle has a rate of change of night power greater than the rate of change of daytime power, and the change rate of nighttime power rate is large, and the change of daytime power rate is small. At the same time, with the increase in the number of access substations and the increase in the rate of charging, the number of electric vehicles connected to the substation during the day has increased linearly, while the number of electric vehicles connected at night has increased linearly and then decreased.

5. Conclusion

Electric vehicles are a kind of clean car, and the development of electric vehicle industry will greatly alleviate the pressure of oil supply and demand and environmental protection, and control the environmental impact and energy consumption to a reasonable extent. After the electric vehicle is connected to the power grid, it can provide FM service, rotating backup service and peak shaving service, and can provide energy storage service for renewable energy, which benefits both the grid operator and the electric vehicle owner. Based on the analysis of electric vehicle access grid technology, this paper combines the East China Power Grid to carry out an example simulation, and draws the daily load curve of the electric vehicle and the current power flow calculation in each year, thus verifying the electric vehicle's access to the power grid. Part of the function reflects its role and influence on the power system.

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References

[1] Wang H, Wu M, Sun J. Analysis of Low-Frequency Oscillation in Electric Railways Based on Small-Signal Modeling of Vehicle-Grid System in dq Frame. IEEE Transactions on Power Electronics, 2015 30 (9) 5318-5330.

[2] Shaukat N, Khan B, Ali S M, Mehmood C A, Khan J, Farid U, Ullah Z. A survey on electric vehicle transportation within smart grid system. Renewable & Sustainable Energy Reviews, 2018 81 S1364032117307190.

[3] Kwon O, Kim P, Yoon Y J. Reduction of control signal overhead for electric vehicle charging

operation in smart grid system. International Journal of Precision Engineering and Manufacturing-Green Technology, 2017 4 (2) 191-197.

[4] Ashique R H, Salam Z, Aziz M J B A. Integrated photovoltaic-grid dc fast charging system for electric vehicle: A review of the architecture and control. Renewable & Sustainable Energy Reviews, 2016 69 1243-1257.

[5] Yun Q X, Jian X J, Ying L W. An Electric Vehicle Charging System Using an SMES Implanted Smart Grid. IEEE Transactions on Applied Superconductivity, 2016 26 (7) 1-4.

[6] Liu H, Yu J, Zhuang H. Multi-Objective Dynamic Economic Dispatch of Microgrid Systems Including Vehicle-to-Grid. Energies, 2015 (5) 4476-4495.

[7] Qian D, Ma C, More K L. Advanced analytical electron microscopy for lithium-ion batteries. Npg Asia Materials, 2015 7 (6) e193.

[8] Cho K, Lim H, Shon T. A novel security architecture of electronic vehicle system for smart grid communication. Journal of Supercomputing, 2015 72 (1) 214-231.

[9] Yang Q, An D, Yu W. Towards Stochastic Optimization-Based Electric Vehicle Penetration in a Novel Archipelago Microgrid. Sensors, 2016 16 (6) 907.

[10] Monteiro V, Carmo J P, Pinto J G. A Flexible Infrastructure for Dynamic Power Control of Electric Vehicle Battery Chargers. IEEE Transactions on Vehicular Technology, 2016 65 (6) 4535-4547.