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Control strategy of electric vehicle access to the power grid based on vehicle-to-grid

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Abstract

In view of the problems of large-scale electric vehicles that are connected to the power grid, the influence of power grid load balance prediction, the safety and stability levels, and the difficulty of centralized control have been analyzed here. Based on this, a charging and discharging control strategy based on vehicle-to-grid has been proposed. The method described this paper can bring about reasonable charge and discharge of electric vehicles, ensure the safe operation of the power grid, and realize the goal of the maximization of users and the power grid.

Keywords: Electric vehicle, V2G, Charge and discharge control strategy

1. Introduction

Electric vehicles [1] have been considered as a new development in the automobile industry and an important growth point for national economic development. In terms of benefits to the state and society, electric vehicles can significantly reduce the consumption and dependence of petroleum and other fossil resources and ensure energy security. At the same time, electric vehicles can considerably reduce urban air pollution and improve urban air quality. For consumers, electric vehicles will considerably reduce travel costs and have high economic benefits. Studies in foreign countries have shown that electric cars consume only one-third of the cost of fuel cars per kilometer.

The popularization and access of electric vehicles will have a considerable impact on mobility and power load characteristics. For example, electric vehicles can considerably increase the load of the grid, increase the load peak valley, and reduce the anti-interference ability of the power grid. This brings uncertainty to the operation and control of the power system, which profoundly affects the safe and stable operation of the power system. An electric car battery is a large-capacity storage device. If we can control the charge and discharge behavior [2], we can balance the power generation and power supply of the power grid, thus facilitating the intermittence of new energy generation. In the field of scheduling optimization of electric cars, intermittent traditional distributed power supply [3], power supply and load matching and balance between relations reduce the risk of power grid operation and running costs, will be an important research direction for a period of time in the future.

2. Influence of Electric Vehicle Access on Power Grid Regulation

A large increase in the number of electric vehicles will allow large-scale electric vehicles to be connected to the grid, which will have a huge impact on the planning and operation of the power grid. These influences mainly include the following aspects:

(1) Load balance[4] and prediction difficulty increase

The massive access and unordered charging of electric vehicles will make load forecasting and load

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control more difficult. First, the charging power of electric vehicles is generally large. Usually, the low charging power of a small car is 8–20 kw, and the quick charging power is over 50 kW. The rapid charging power of large electric vehicles such as electric buses can reach hundreds of kilowatts. In areas where electric vehicle penetration rates are large, a large number of such vehicles connected to the grid will generate new load peaks and exceed the load capacity of existing equipment. Research has shown that with the current technology in electric vehicles, when the electric vehicle penetration rate reaches 20%, the typical power system will be unable to accommodate all electric vehicles. Second, as a type of liquid high power load, the charging behavior of electric vehicles is closely related to human production and life. It has the characteristics of spatiotemporal randomness, intermittence, and sociality. After an electric vehicle is connected, the uncertainty of load center, load size, and time of load peak valley increases considerably, making the load forecasting work particularly difficult. To cope with the peak load at any time, the dispatching department needs to constantly adjust the output curve of the power plant and increase the rotation reserve capacity of the generator set. The efficiency and efficiency of grid equipment utilization are reduced. Moreover, with the accumulation and dispersion of electric vehicles, it may lead to local overload or three-phase imbalance of the power grid, and the local supply and demand balance of the power grid are broken. At this time, to ensure the provision of a reliable power supply to the user and ensure that the equipment is not damaged due to overload, the dispatching department has to respond by means of dumping. This will lead to a marked increase in the workload of regulatory operations.

(2) Safety and stability of the power grid are reduced

An electric car charger uses a large number of power electronic devices; the access of the inevitable impact on the power grid, including reducing power grid reliability, causes a low-voltage distribution network, increases power grid harmonics, and causes three-phase unbalance. At the same time, due to the poor overload capacity of power electronic devices and the large amount of reactive power support of the power grid, it is more sensitive to the voltage fluctuation of the grid. When the power grid is connected to electric vehicles on a large scale, there will be a chain reaction when there is power failure or an abnormal situation. Power electronic devices are self-protected and will remove electric vehicles from the grid. The power balance is further broken, and the anti-interference ability of the power grid is greatly reduced.

(3) Centralized regulation of power grid is difficult to achieve

To decrease the difficulty of scheduling and give full play to the electric car energy storage characteristic peak to peel and given new energy power generation, efficiency, improve the operation of the electric car orderly grid is becoming a hot spot of research. Current work has mainly studied the orderly charging of electric vehicles and the two-way interactive power supply between electric vehicles and the power grid [vehicle-to-grid (V2G)]. Among them, V2G[5-7] has received considerable attention. V2G refers to the two-way interaction between electric vehicles as mobile energy storage units and power grids for information and energy. Its core idea is to connect idle electric cars to the grid when time and battery capacity are allowed. When the grid load is too high, electric vehicle storage energy is dispatched to feed the power grid. When the grid load is too low, the excess energy in the grid is stored in electric vehicles. Through the corresponding optimization and scheduling method, V2G can solve the problem of electric vehicle charging and avoid the adverse effect of the charging cluster effect on the power grid. At the same time, it can respond to the frequency of the power system, reduce the peak valley difference in the regional power grid and fluctuation in renewable energy, maintain the efficient and safe operation of the power grid, and reduce operating costs. Furthermore, electric car users can charge at low electricity prices, feed electricity to the grid at the peak of the electricity price, and reduce the cost of electric cars.

The implementation of V2G requires the unified regulation of a large area with relatively stable power supply and demand (such as a provincial power grid). In other words, the control center and each electric vehicle in the region will establish communication channels to collect the battery power of the car in real time and send dispatching instructions. Considering that the number of electric cars in the future will be very large, the reliability and real-time requirement of the communication channel are very high. Centralized control is very difficult, and therefore, there is a need to establish an effective control strategy of electric vehicle charging and discharging.

3. The Electric Vehicle Charging and Discharging Control Strategy Based on V2G

For a large number of electric vehicles, decentralized access and the centralized management mode have been adopted. The whole control process adopts hierarchical control models, including grid dispatching send scheduling command to the electric car control center and the electric car control center to the electric car distribution of individual power two control layers, as shown in Fig. 1.

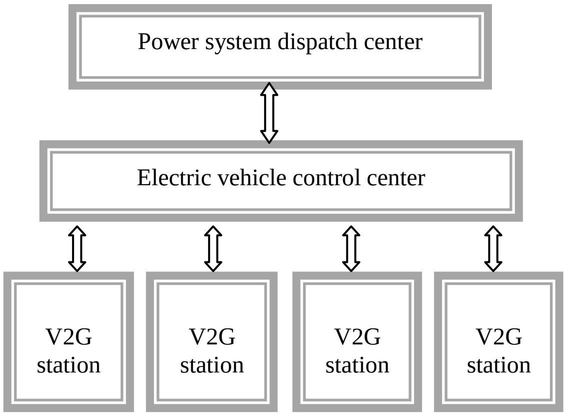

Fig. 1. V2G participates in the hierarchical control schematic of the power system auxiliary service.

The two-way energy exchange control between the electric vehicle and power grid involves three independent criteria as shown in Fig. 2: power grid dispatching center, electric vehicle control center, and electric vehicle.

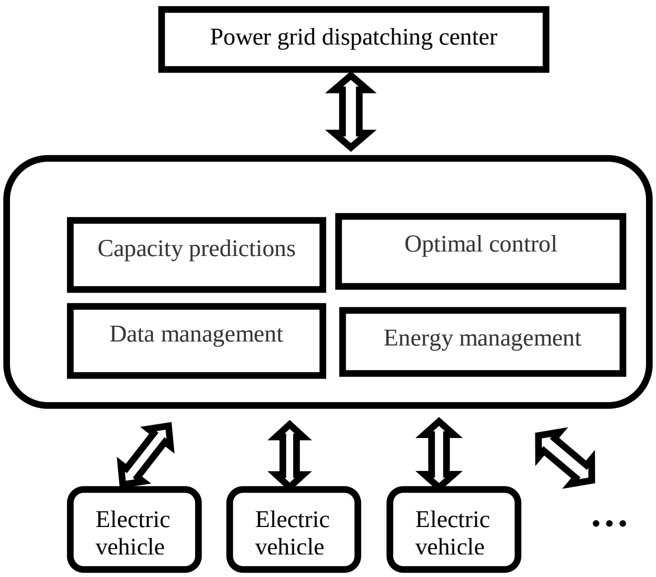

Fig. 2. System framework of V2G.

(1) Power grid dispatching center

The power grid dispatching center can use the electric vehicle capacity of an electric vehicle control center as a special power supply. The response power range of traditional power supply is a range higher than zero, while the response range of V2G can be extended to a negative value. The integrated electric vehicle control center provides information on the range of adjustable capacity and load forecasting, and the power grid dispatch center sends the dispatch order to the electric vehicle control center. The scheduling command can be a charging or discharging plan or a frequency control instruction.

(2) Electric vehicle control center

The randomness, dispersion, and mobility of electric vehicle access require an entity to manage it. The electric vehicle control center manages and controls all electric vehicles, allowing all electric vehicles it manages to participate in power system services. An electric vehicle control center can manage one or more V2G stations. The electric vehicle control center system includes an adjustable capacity prediction module, a charge and discharge control module[8], an energy management module, and a data management system.

The adjustable capacity prediction module predicts the available capacity range of V2G at each time period. Through the data management system, the statistical information of V2G can be obtained in real time (including the increase in total capacity, reduction in total capacity, and number of electric vehicles involved). Real-time information and historical data can predict the range of available capacity at any time, and the electric vehicle control center can upload it to the power grid dispatch as a reference basis for dispatching instructions. As some electric vehicles do not operate accurately according to their pre-set state, the expected available capacity and actual capacity may be biased. As the number of electric vehicles increases, the prediction error will become smaller.

The main function of the charge and discharge control module is to provide the total capacity of charge and discharge and real-time load information of the current power grid according to the energy management system. It adopts an appropriate charging and discharging control algorithm to determine the charging and discharging power of electric vehicles in the area. The control target can be profit maximization, load response effect optimization, and others.

The main function of the energy management module is to monitor the working condition of the on-board battery pack in real time, provide basic data of the charging and discharging strategy, and provide secondary distribution instructions for each charging and discharging machine. The data management system collects and manages all electric vehicle information. Vehicle information, including whether they are connected to the Internet, the battery to adjust power, current and future period of time, power grid power auxiliary service time, position of the electric car, and some battery status information in real time. To guarantee the capacity of V2G for long-term management, the power grid dispatch can sign bilateral contracts with electric car owners.

(3) Electric vehicle

The owner of the battery can decide to participate in the grid service when the battery is idle. Users can send signals to the electric vehicle control center and real-time communication to bring about electric vehicle information upload. The electric car owner can set up, update, and modify according to travel demand and then update the database information. Moreover, the state of electric vehicles can be inquired. When the power market mechanism is mature, real-time pricing information can be checked at any time.

4. Conclusion

The large-scale use of electric vehicles will have a revolutionary impact on the power system. Electric vehicles markedly increase the power grid load, and their energy storage characteristics make grid energy flow in two directions; the intermittence of new energy plays a role of smoothing and buffering. In this paper, the charging and discharging control strategy of an electric vehicle based on V2G has been proposed to optimize the charging and discharging behavior of electric vehicles. The strategy can reduce the charging cost and network loss to the maximum extent, make the most use of new energy to generate electricity, reduce the intermittence of new energy, and cut peak filling. Finally, it can result in a minimum operating cost and a minimum environmental impact.

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