Application of PV-assisted Intelligent Electric Vehicle Charging and Switching Power Station

Ye Wang

China Aviation Planning and Design Institute CO.,LTD, Beijing, Province, 100120, China

Corresponding author’s e-mail: wangyedq@avic-aic.com

Abstract. Taking a new office area as an example, this paper introduces the design of power supply and distribution system for traditional electric vehicle charging pile. In view of the adverse impact of large-scale EVs load on the power grid, a photovoltaic charging and switching power station microgrid system is proposed, and intelligent dispatching is carried out through the energy management system. The scheme combines the development of clean energy with the supporting facilities of electric vehicle, which can effectively solve the problems caused by the connection between new energy and power grid, and improve the quality of power grid. The Energy Management Strategy reduces the impact of traditional charging stations on the urban distribution network and the consumption of urban electricity during peak period, and has higher economic benefits.

1. Introduction

As the number of private electric vehicles increases, the proportion of electric vehicle power consumption to total electricity consumption, and the proportion of peak charging power to generator capacity will increase significantly [1]. When Electric Vehicles (EVs) are charging without order, extremely high charging peaks will be generated under extreme circumstances [2-4]. If the new power demand is met by means of increasing the installed capacity and the scale of power grid construction, the utilization ratio of power grid equipment will be greatly reduced, causing the waste of power grid resources [5].

The output of renewable energy such as wind and light is intermittent, changeable and uncertain [6]. This feature makes it difficult for renewable energy facilities to operate alone and requires some power compensation or power smoothing measures, including the absorption of large power grids (regulating units with controllable output in large power grids), and demand response or demand side management. After a large number of distributed power sources are connected to the power grid, the distribution network becomes a two-way power exchange system with the line power flowing from top to bottom. However, the current distribution network is designed according to one-way power flow, which does not have the potential to effectively integrate a large number of distributed power sources [7-10].

The best way to solve this problem is the development and absorption of renewable energy on the spot [11]. Electric vehicle is not only a controllable load, but also an important distributed energy storage device. It can not only reduce the impact on the power grid when using a large number of charging piles, but also promote the development of renewable energy.
2. Design of Power Supply System for Traditional Electric Vehicle Charging Pile

In order to promote the construction of electric vehicle charging facilities, different measures have been issued. Electric vehicle charging facilities should be set up according to the following requirements: office buildings should not be less than 20%, commercial buildings and social public parking lots should not be less than 15%.

Figure 1. Schematic diagram of the power supply and distribution system

![Figure 1. Schematic diagram of the power supply and distribution system](image)

Take a new office area as an example, at least 160 of the 800 parking spaces need to be equipped with charging piles or have the conditions to install charging piles.

The load capacity of charging equipment can be calculated according to the following formula:

\[ S_{js} = K_t \times \left[ K_{X1} \times \sum P_1 + (\eta_1 \times \cos \phi_1) + K_{X2} \times \sum P_2 + (\eta_2 \times \cos \phi_2) \right] \]

in which, 
- \( S_{js} \) —— calculation capacity (kVA);
- \( \cos \phi_n \) —— power factor, generally >0.90;
- \( \eta_n \) —— working efficiency, generally take 0.95;
- \( \sum P_n \) —— total rated power;
- \( K_{Xn} \) —— coefficient of demand;
- \( K_t \) —— coefficient of simultaneous use, the number of charging equipment (slow charge + fast charge) between 5-50, take 0.9-0.95; more than 50, take 0.8-0.9.

Using 7kW single-phase AC charging piles and 30kW three-phase AC charging piles, the transformer capacity needs to be increased by 1600kW, according to the 1:5 calculation of fast and slow charging ratio. The power can be directly supplied from the low voltage side of the transformer in the building or by a new special transformer, as shown in figure 1.

3. Influence of Large-scale EVs Load on Power Grid

The parking time of vehicles in the office area is relatively stable, generally from 8:30 am to 17:00 pm, which is basically consistent with the peak and valley period of power grid load. The parking time follows normal distribution, and the number of vehicles with parking time between 7-10 hours accounts for 90% of the total number of electric vehicles.

Large-scale EVs load on power grid has the following effects on distribution networks:

3.1 Impact on distribution system load

When the charging load of EVs is superposed with the conventional load, the peak value of the load increases obviously, which leads to the further increase of the system peak-valley difference ratio. The larger the scale, the more obvious the effect is. When the permeability reaches a certain degree, the maximum load will be overloaded. Thus it is necessary to reform and expand the capacity of the
power grid, which increases the operating cost, and the expansion of the peak-valley difference ratio will further reduce the economy of the power grid.

3.2 Effect on Network Loss
Network loss is an important index of economic operation of power grid. When the total load is fixed, the smoother the load curve, the smaller the network loss. When the permeability of electric vehicle increases continuously, the load loss rate of the line increases rapidly. When the no-load loss rate of the transformer is constant, the loss rate of the whole line increases greatly, and the line transitions to the non-economic operation area.

3.3 Impact on Power Quality
According to the relevant regulations of power quality in China, the voltage offset allowed by users below 10kV is 7%. High permeability electric vehicle charging will affect the line node voltage, especially the terminal node voltage, and the normal power consumption of users.

The charging facilities of electric vehicles belong to nonlinear power electronic equipment, and their access will produce harmonic pollution to the power grid. If they are not treated, they will cause voltage distortion and power factor decline, which will affect the normal operation and life of capacitors and transformers.

4 Microgrid System of Charging Station with Photovoltaic
The output of photovoltaic system is intermittent and random. The integration of photovoltaic and electric vehicle charging will not bring additional transmission and distribution pressure to the city center. On the contrary, the power battery of electric vehicle used as energy storage device can effectively alleviate the intermittent fluctuation of light output power.

The electric vehicle charging and switching power station with photovoltaic power generation system can be seen as a typical microgrid system, and its physical structure is shown in figure 2.

![Figure 2. Structure Chart of PV Charging Station for Electric Vehicles](image)

The microgrid system includes four units: photovoltaic power generation system, equivalent load in the station, battery pack in charging and discharging area, electric vehicle. The bus in the station has AC bus and DC bus, and the AC/DC bus is connected by inverter. The photovoltaic system and battery pack in the station are connected to the microgrid AC bus through their respective inverters. The charging station microgrid system is connected to the distribution network through a unique public contact point PCC (static switch). When the static switch is closed, the charging power station is in a grid-connected operation mode, and when it is off, the charging power station is in an off-grid operation mode.

During the low period of electricity consumption, the distribution network can supply the load of the microgrid and energy storage battery at the same time because of the cheap electricity and the small load pressure.
During the normal period of electricity consumption, photovoltaic power generation is preferred to supply power to the load of microgrid system. If the electric energy emitted by photovoltaic module cannot meet the demand of the load in the system, it is necessary to supply the load with city power. If the photovoltaic module emits more power than the load demand, the photovoltaic module also supplies power to the energy storage module.

During the peak period of electricity consumption, due to the large capacity of the distribution network and the high unit price of electricity, the electric energy of photovoltaic module is preferred to supply power to microgrid system. If the electric energy emitted by photovoltaic module cannot meet the demand of load, the energy storage module is used to supply power to load at the same time. If the photovoltaic module emits more electricity than the load, the photovoltaic module also supplies power to the energy storage module. When there is still surplus power generation in microgrid, excess electric energy can be incorporated into large power grid to reduce waste.

5 Intelligent Dispatching

In the future, the new distribution network is different from the simple distribution network at the present stage. The network undertakes the conversion, alternation and utilization of various energy sources, such as electricity, gas, cold and hot. It is a new type of information-energy integrated "wide area network ", which can be called energy Internet. It is based on the ideas of Internet. Energy autonomous units such as microgrid and distributed energy are used as "local area networks" to realize two-way on-demand transmission and energy dynamic balance through open peer-to-peer information-energy integration architecture.

The energy management system is responsible for regulating the operation of the components of the system and monitoring the energy. It can be divided into unit layer, microgrid layer and distribution network layer, and its topology is shown in figure 3.

Figure 3. Topology of Energy Management Systems

The unit layer is composed of PV unit, EVs unit, Energy Storage unit and its measurement and control terminal. The unit measurement and control terminal completes the voltage and frequency adjustment of the distributed power supply and the electric vehicle. The load measurement and control terminal removes the unnecessary load according to the real-time demand of the system, and monitor load access status and power changes to ensure the safe and stable operation of the system.

The microgrid layer is composed of microgrid controller and microgrid energy management system. The microgrid energy management system makes a plan and sends it to the microgrid controller based on the energy output and consumption of each generation unit and load unit in the unit layer; the microgrid controller realizes the coordinated and optimized control of the distributed generation unit, the energy storage unit and the load unit to make sure the operation stability and smooth switching between the two operating states. The microgrid controller realize the real-time information interaction in the distribution network layer as the communication interface between the distribution network and the microgrid.

The distribution layer is composed of distribution network dispatching system. The distribution network dispatching system communicates with the microgrid controller in real time to obtain the
energy output and consumption of each generation and load unit in the unit layer, combined with the real-time dispatch command of large power grid, the microgrid generation plan is made and sent to the microgrid controller.

When charging the electric vehicle, the energy management system receives the data of the charger and the real-time photovoltaic output of the photovoltaic power generation system, and then processes these data to obtain the data such as the charging feasible region, the photovoltaic output, the total charging power, the vehicle departure time, and the battery adjustable coefficient. During the discharge, the energy management system first receives the data of power demand, then combines the data of battery capacity, discharge intention and driving time of the electric vehicle to control the discharge process.

6 Conclusion
The potential of electricity saving in China is huge. The photovoltaic module is laid on the roof of the building or outdoor charging station in the factory area or plot, which does not need to occupy the additional land area. The electric energy emitted by photovoltaic module gives priority to the load in DC microgrid, which reduces the transmission link of electric energy. The use of energy storage device makes the power of DC microgrid controllable and improved, and reduces the influence on the power grid when interacting with the power grid, and maintains the security and stability of the power grid. Electric vehicles are not only high-power electrical appliances, but also can be used as energy storage devices in the power grid. The management of these mobile energy storage devices can lay a solid foundation for the large-scale cooperation of light, storage and charging, and promote the development of smart-grid.

References
[1] Haiyan An. (2011) Study on Policy of New Energy Automobile Industry in China. Modern Business Trade Industry, 15:1-2
[2] P. Mitra and G. K. Venayagamoorthy. (2010) Wide Area Control for Improving Stability of A Power System with Plug-in Electric Vehicles. IET Generat.,Transmiss. Distrib., 10(4): 1151-1163.
[3] Hong Liu, Long Wang, Saiyi Wang. (2013) Impact of PV and Battery Storage on the Power Supply Reliability. Applied Mechanics and Materials, 380:2958-2961.
[4] Putrus G A, Suwanapingkarl P, Johnston D. (2009) Distribution networks with electric vehicles. IEEE Vehicle Power and Propulsion Conference. Michigan: IEEE, 827-831.
[5] Liting Tian, Mingxia Zhang, Huanling Wang. (2012) Evaluation and Solutions for Electric Vehicles’s Impact on the Grid. Proceeding of the CSEE, 32:43-49.
[6] Ming Ding, Ningzhou Xu, Rui Bi. (2011) Modeling of BESS for Smoothing Renewable Energy Output Fluctuations. Automation of Electric Power Systems, 35:66-72
[7] Haoyu Shang, Tianqi Liu, Tao Bu. (2020) Operational Risk Assessment of Power System Considering Wind Power and Photovoltaic Grid Connection. Modern Electric Power, 37:358-367
[8] Rui Ma, Wenwei Yuan. (2011) An Approach for Determining Voltage Collapse Critical Point based on Monte Carlo Stochastic Line Selection Optimal Power Flow. Power System Protection and Control, 39:65-69.
[9] Haiying Wang, Xiaomin Bai, Gang Ma. (2012) Reliability Assessment of Grid-integrated Solar Photovoltaic system. Power System Technology.36:1-5
[10] W. Kempton and J. Tomic.(2005) Vehicle-to-grid Power Implementation: From Stabilizing the Grid to Supporting Large-scale Renewable Energy. J. Power Sources, 144. 280-294.
[11] Ahmed Y S, Ganesh K V. (2011) Plug-in Vehicles and Renewable Energy Sources Forcost and Emission Reductions. IEEE Transactions on Industrial Electronics,58(4): 1229-1238.