A New Charging Strategy Suitable for Electric Vehicle Charging Station in New Energy Occasions

Xinlei Cai, Kai Dong, Yuhang Huo, and Xiangzhan Meng

Abstract In order to promote the consumption of photovoltaic (PV) energy by Electric Vehicles (EV), a battery charging strategy for electric vehicle charging stations in new energy occasions is proposed. This strategy considers traffic information and weather information in each period, and takes road saturation and temperature as the impact indicators of EV charging demand. On the basis of calculating the instantaneous power of the PV battery, the actual power of the charging station is calculated. In order to maximize the utilization rate of PV, the charging power of the EV is compared with the PV power generation during this period to determine the period of time. Electric vehicle charging rate. Compared with the constant power charging strategy, the charging rate of the proposed strategy greatly reduces the energy waste caused by the charging process, improves the consumption rate of new energy, and reduces the impact of the grid connection of new energy and EV on the main network.

Keywords EV · New energy power generation · Variable speed charging · Optimized scheduling

1 Introduction

The continuous increase of EV ownership and the continuous maturity of battery technology make EV batteries as a new type of load begin to be connected to the grid in large quantities. Disorderly charging of a large number of EV batteries will have a large impact on the operation of the power system. For example, large-scale disordered access to the power grid will increase the peak load and affect the safe

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and stable operation of the power grid. The large-scale integration of intermittent new energy into the grid will lead to insufficient power grid peaking resources. The harmonics generated by charging will also affect the power quality. As a new type of "flexible load", EV battery has dual functions of source and load. If it is regulated, its value in participating in auxiliary services of power system and absorbing new energy cannot be ignored.

Considering the new energy consumption of EV batteries and the reasonable distribution of charging station power are effective measures to ensure grid load shaving peaks and valleys and meet the individual needs of users for charging. Aiming at the problem of controlled charging demand, Yang Dingtong et al. proposed a method to quickly generate demand estimates to represent the EV charging demand of millions of people in a large-scale charging station scenario [1]. In order to achieve reasonable distribution and real-time management of power, Powell Siobhan et al. proposed a stochastic dynamic simulation modeling framework for the regional system of EV charging stations, considering the needs and selection of each EV's fast charging, effectively promoting the utilization of PV energy consumption problem and charging station revenue problem [2]. However, the above methods do not take into account the problem of hybrid energy storage. In order to make efficient use of energy in charging stations, Jiang Hong et al. applied interval type II fuzzy logic control to hybrid energy storage systems, and used bidirectional DC/DC converters for hybrid energy storage. And the perturbation observation algorithm is used to track the maximum power of the solar panel [3]. The charging demand of EV affects the power allocation of charging stations. Wang Cong et al. described the real-time optimal power allocation of EV in charging stations as a nonlinear optimization problem with linear constraints [4]. On the basis of the simplified average switch model and impedance model, a control method combining droop control and voltage support control was reasonably applied by Chen Xinxing et al. stability [5]. Considering the typical charging current and voltage characteristics of EV battery packs is the basis for realizing power distribution in the station, Giuseppe Graber et al. solve the charging scheduling problem by grouping energy, improve the QoS level, and make power distribution more economical and convenient [6].

Based on the above analysis, this paper designs a variable speed charging method including photovoltaic power charging stations, and builds a comparison model between photovoltaic battery power and charging station real-time power, which promotes the ability of EV batteries to absorb new energy.

2 Integrated System Structure of Charging Station with PV Power Source

2.1 System Composition and Function

The structure of the integrated system of the charging station with PV is shown in Fig. 1. Except for EV, this system is mainly composed of PV panels and grid, centralized battery charging station and energy management system. The functions of each part are as follows:

1) PV panels and grid: PV and grid are the two energy sources for photovoltaic charging stations, i.e. solar panels generate a lot of electricity, which may even exceed the typical needs of battery charging stations during the sunny summer day, while the PV power output at night is 0.
2) Centralized battery charging station: The main purpose of the battery charging station is to charge the discharged battery pack [7]. The power demand of the battery charging station and the optimization of the charging strategy are the core content of this paper.
3) Energy management system: The platform controls and adjusts the battery charging rate, and at the same time needs to consider factors such as climate, road traffic, and the number of electric vehicles in operation, so as to realize local photovoltaic consumption and ensure the economical operation of the entire system.

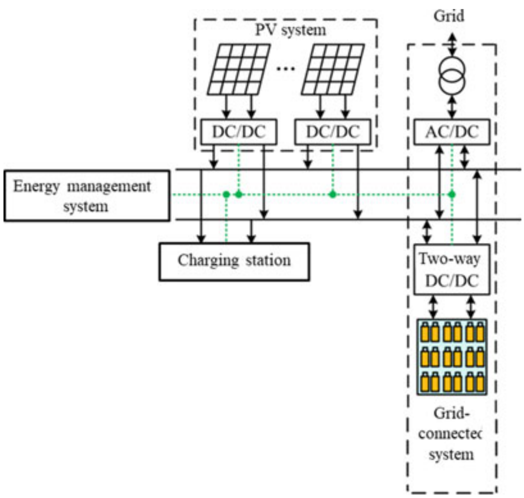

Fig. 1 System structure of charging station with PV power source

3 Design of Variable Speed Charging Mechanism for EV

3.1 PV Cell Instantaneous Power

In the system of this paper, the controller will control the battery charger to preferentially use the power from the photovoltaic, and then purchase the power from the grid when the photovoltaic output is insufficient. PV panel output power is directly related to the peak power and light intensity where it is installed. The peak power of PV, also known as rated power, refers to the power output at a light intensity of 1000 W/m^2 and an ambient temperature of 25 °C. In practice, the PV output is almost linear with the instantaneous solar irradiance. Ignoring the effect of wavelength, the instantaneous power of a photovoltaic cell can be expressed as:

$$PV(t) = P_{ed} \cdot \frac{Ra(t)}{1000} \tag{1}$$

where, t is the time, PV is the photovoltaic output power, P_{ed} is the rated power of the photovoltaic panel, *Ra*(t) and is the solar irradiance.

3.2 The Number of EV on the Station in the Future Period

According to historical information, the number N_1 and the state of charge SOC of visiting electric vehicles at various time periods throughout the day are predicted. Assuming that a time period is 15 min, the battery charging rate is constant within a time period, that is, the charging piles are charged upon arrival, and the number of charging piles is unlimited.

From the number of electric vehicles visited at the initial moment *i*, the number of electric vehicles in the station at the next moment can be obtained:

$$N_2(i+1) = N_1(i) - N_1^m(i) + N_1(i+1) \tag{2}$$

where, $N_1(i)$ is the number of electric vehicles visited at the *i*-th time; $N_1^m(i)$ is the number of electric vehicles that have been fully charged at the *i*-th time and withdrawn from charging; $N_1(i+1)$ is the number of electric vehicles visited at the $i+1$-th time. $N_2(i+1)$ is the number of electric vehicles in the charging station in the $i+1$-th period.

Then the number of electric vehicles standing at any time period can be obtained [8]:

$$N_2(i+t) = N_1(i) - \sum_{i}^{i+t-1} N_1^m(i) + \sum_{i}^{i+t} N_1(i+1) \tag{3}$$

where, $N_2(i+1)$ is the number of electric vehicles in the charging station in the $i+t$ period.

3.3 Charging Station Actual Power Calculation

First, the electric vehicles in the charging station are divided into three categories according to the state of charge; the state of charge SOC is between (0.8–0.95), which is high power; less than 0.5 is low power; the rest are medium power; For an electric vehicle with a high state of charge, considering the battery life, the electric vehicle is always charged at the slowest rate regardless of the amount of photovoltaic power [9]. The number of electric vehicles in high power state is N^g; the number of electric vehicles in medium power state is N^z; the number of electric vehicles in low power state is N^d.

Calculate the charging power of the charging station in each period. When all electric vehicles are charged at the minimum rate, the charging power is the smallest at this time:

$$P_{\min}(i) = \frac{N_2(i) \cdot P_{ev}^{\min}(i) \cdot S_b}{4} \tag{4}$$

where, $P_{\min}(i)$ is the minimum charging power of the charging station in the i period; $N_2(i)$ is the number of electric vehicles in the charging station in the i period; $P_{ev}^{\min}(i)$ is the minimum charging rate of the electric vehicle battery; S_b is the rated capacity of the battery.

High-battery electric vehicles are charged at the minimum rate, and all other electric vehicles are charged at the maximum rate, at which time the charging power is maximum:

$$P_{max}(i) = \frac{N^g(i) \cdot P_{ev}^{\min} \cdot S_b}{4} + \frac{(N^z(i) + N^d(i)) \cdot P_{ev}^{\max} \cdot S_b}{4} \tag{5}$$

where, $P_{max}(i)$is the maximum charging power of the charging station in the i period; N^g, N^z, N^d is the number of electric vehicles whose battery state of charge is high, medium and low in the charging station in the i period; $P_{ev}^{\max}$, $P_{ev}^{\min}$ is the maximum and minimum charging rate of the battery.

Therefore, the actual charging power of the charging station,

$$P_{max}(i) \geq P(i) \geq P_{\min}(i) \tag{6}$$

where, $P(i)$ is the actual charging power of the charging station.

3.4 Calculation of Charging Rate of Each Battery in the Station

In order to maximize the utilization rate of PV, the battery charging in the charging station is divided into three categories for discussion according to the comparison between the PV and the $P(i)$ [10].

1) $PV \leq P_{\min}(i)$, it is necessary to purchase electricity from the grid to meet the normal operation of the charging station, including:

$$P_g(i) = P_{\min}(i) - PV(i) \tag{7}$$

$$P(i) = P_{\min}(i) \tag{8}$$

where, $P(i)$ is the charging power of the charging station in the i period; $P_g(i)$ is the power purchased by the charging station from the grid in the i period.

At this time, the charging rate of the electric vehicle in the charging station is:

$$P_{ev}(i) = P_{ev}^{\min}(i) \tag{9}$$

2) $P_{\min}(i) \leq PV(i) \leq P_{\max}(i)$, $P(i) = PV(i)$. The charging rate of electric vehicles in the charging station is:

$$P_{ev}(i) = \frac{(PV(i) - P^{g}(i)) \cdot 4}{N \cdot S_b} \tag{10}$$

where, $P^{g}(i)$ is the charging power of the battery whose state of charge is high;

$$P^{g}(i) = \frac{N(i) \cdot P_{ev}^{\max}(i) \cdot S_b}{4} \tag{11}$$

3) $PV(i) \geq P_{\max}(i)$, $P_g(i) = 0$, $P(i) = P_{\max}(i)$.

At this time, the electric vehicles in the charging station are charged at the maximum charging rate:

$$P_{ev}(i) = P_{ev}^{\max}(i) \tag{12}$$

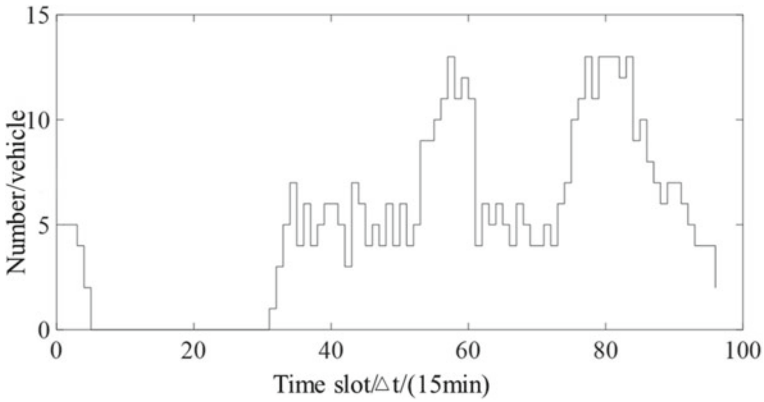

Fig. 2 Prediction data of visits to electric vehicles at charging stations at different times

4 Validation of Variable Speed Charging Strategy

4.1 Basic Data

To further illustrate this strategy, take an area with sufficient light as an example, assuming that there are 200 electric vehicles in the area, this system provides charging services for these 200 electric vehicles, and the installed photovoltaic capacity is 1200 kW. The solar irradiance data adopts the actual data from a photovoltaic power plant in Mengxi. Figure 2 shows the number of electric vehicles that visit the charging station during each time period through the prediction. The maximum charging rate is 2C, the minimum charging rate is 0.5C, and the rated battery capacity is 60 KWh. The algorithm adopts particle swarm algorithm with 50 particles and 300 iterations.

4.2 Comparative Analysis of Variable Speed Charging and Constant Power Charging Models

The results of the comparison between the variable speed charging strategy and the constant power charging strategy are shown in Fig. 3 below. It can be seen that the utilization rate of solar energy by the variable speed charging strategy is significantly higher than that of the constant power charging model. Among them, the solar energy used by the all-day constant power charging strategy is 7727.56 KWh, the solar energy used by the variable speed charging strategy is 8925.96 KWh, and the solar energy utilization rate is increased by 15.5%. Therefore, the variable speed charging strategy proposed in this paper effectively improves the utilization rate of solar energy and has high practicability.

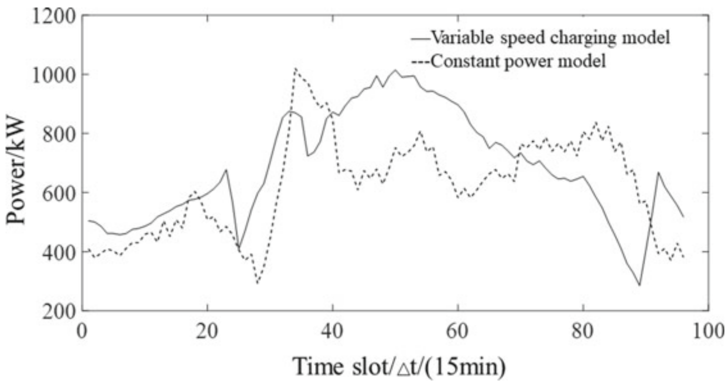

Fig. 3 Comparison of EV charging power between constant power charging and variable speed charging models

5 Conclusion

In this paper, the variable speed charging mechanism is integrated into the power optimization scheduling model of the charging station integrated system, and the charging rate of the battery in each time slot is flexibly adjusted according to the photovoltaic and traffic forecast information. In order to maximize the utilization of PV, the actual power of the charging station is compared with the actual power of PV, and the battery charging in the charging station is divided into three categories for discussion [11]. According to the comparison results between the variable speed charging strategy proposed in this paper and the constant power charging, it can be seen that this method improves the photovoltaic utilization rate, and the solar energy utilization rate increases by 15.5% when the light is sufficient, which verifies the effectiveness of the charging strategy. The optimization model in this paper provides an effective method for promoting new energy consumption, power optimization scheduling of charging stations including photovoltaic power sources, and participating in grid peak shaving operation.

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