The operating mode of electric vehicles and its impact on renewable energy consumption

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Abstract. Nowadays, under the dual pressure of fossil energy shortage and ecological environmental pollution, new energy vehicles have flourished in our country by virtue of their clean and low noise advantages. But correspondingly, the grid connection of electric vehicles will also bring many problems. Therefore, this article attempts to explore the operating mode of electric vehicles and its impact on the consumption of renewable energy, so as to provide reasonable planning of charging facilities and improve the top-level design of the grid.

1 Introduction

In recent years, with the increasing shortage of fossil energy and the pollution of ecological environment, people's awareness of environmental protection is gradually enhancing. Because new energy vehicles do not rely on traditional oil and low pollution, noise-free, market share generally climbed. It is estimated that the number of electric vehicles will exceed 25 million by 2025, 80 million by 2030 and 160 million by 2035, which means that electric vehicle will be one of the largest loads in the future power grid, and its scale effect makes the grid face many challenges.

On the one hand, the charging infrastructure of electric vehicles is connected to the power system on a large scale, which affects the distribution network transmission and distribution, power supply, power quality and load aggregation scheduling. The randomness of electric vehicle charging behavior will not only lead to the increase of power grid load, but also make the grid load gather in a certain period of time for charging, which leads to a series of problems, such as the sharp increase of power demand, the mismatch of power supply and demand, the decline of power quality, and the shortage of power supply¹.

On the other hand, the new round of energy reform focuses on the transformation of traditional fossil energy to clean energy. At present, with the rapid development of new energy power generation technology, wind and solar power generation is moving towards a new situation of large-scale development and utilization. However, the randomness and volatility of renewable energy integration will lead to the increase of peak valley difference of grid load. With the increase of renewable energy penetration in distribution network, it will cause great pressure on the safe and stable operation of grid voltage, and the difficulty of voltage control of distribution network will also increase sharply.

Although the wide access of electric vehicle charging and renewable energy has randomness, at the same time, electric vehicles are also energy storage units located at the end of the grid, which, as distributed energy storage, can provide power systems with considerable flexibility resources, thus effectively increasing the grid's ability to eliminate renewable energy sources.

To sum up, this paper mainly studies the operation mode of electric bus and its impact on renewable energy. Through the analysis of charging characteristics and actual data of electric bus, it guides the reasonable planning of charging facilities, solves the impact on the power grid when it is connected to the power grid, enhances the flexibility of the power grid, and improves the absorption capacity of renewable energy.

2 Operation mode of electric bus charging station

According to the charging types, electric buses at home and abroad can be divided into conductive (wired) charging and wireless charging, and conductive charging can be divided into vehicle charging and battery changing mode. Wireless charging mode refers to charging the vehicle power battery with radio energy transmission technology. At present, cable charging is the main charging mode of electric buses in China, which mainly includes four modes: online charging mode, centralized charging mode, slow charging mode and fast charging mode. The operation scale of online charging mode is small, and it mainly uses the urban trolley bus to charge for a certain distance, and uses the mode of on-board battery power supply for a certain distance. For the centralized power exchange mode, the charging station provides a special power exchange channel, so that each vehicle can change power in a short period of time, which

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can ensure the high efficiency of the electric bus. However, the disadvantages are relatively obvious. The station covers a large area and requires a large number of backup battery. Frequent replacement will cause great loss to the bus frame, and the electrode plug has problems such as spark and wear. For slow charging mode, the power supply of electric buses is mainly at night, because of the large capacity of electric bus on-board power battery, the investment cost is higher.

At present, fast charging is a common charging mode adopted by most electric bus charging stations in China. In this charging mode, the electric bus can make use of it to realize fast power replenishment during the parking period.

Departure scheduling mainly includes train operation plan and real-time scheduling. Among them, train operation plan refers to arranging departure schedule according to line and vehicle conditions, and arranging various driving plans based on passenger flow parameters and speed parameters in different periods. The real-time dispatching requires that multiple lines can be switched, the departure mode can be edited (planned departure, manual departure, flow departure), and the plan adjustment (personnel, vehicle increase number, etc.) can be realized quickly.

3 Charging load characteristics of electric buses

Take Xiaoying charging station as an example. There are 25 sets of 360kW high-power DC chargers and 5 sets of 90kW DC chargers in the charging station, which can charge 30 buses at the same time. The charging station serves 192 electric buses. The power batteries for electric vehicles come from three manufacturers: Mengculi, Weihong and Yinlong. According to the statistics for the whole year of 2017, the total annual mileage of the three routes of buses is about 3 million kilometers, the total annual charging capacity of the charging station reaches 3.2 million kWh, the total number of charging is about 86,000 times, and the average daily charging is 12,000 kWh. , The average number of recharges per day is about 320.

The total power consumption of a bus is shown in the figure below. The average monthly electricity consumption is about 36100 kWh, and the annual total power consumption is 434000 kWh. Among them, the electricity consumption in January, February, November and December is generally higher than that in other months, which is mainly due to the large energy consumption of air conditioning heating in winter.

According to actual statistics, the total annual frequency of a certain bus is 21,287. Due to the short mileage of the whole journey, it is generally charged once for two laps, and occasionally for three laps. The average value of the initial SOC when the bus is charging is 0.68, the actual distribution interval is [0.34,0.82], the average actual charging time is 10-11 minutes, and the distribution interval is [6,36] minutes.

The figure below shows the average energy consumption per unit mileage of a certain electric bus in each month. It can be seen that the value of energy consumption per unit mileage fluctuates around 1 kilowatt-hour per kilometer. Overall, the energy consumption in winter is slightly higher.

4 Electric vehicle charging mode

According to the purpose, electric vehicles are divided into private cars, business cars and taxis. According to the charging mode, electric vehicles are divided into fast charging mode and slow charging mode. For private cars and most business vehicles that do not have strict requirements on charging time, their driving routes and charging locations are relatively fixed, and they are suitable for slow charging in scattered charging piles.

For taxis and commercial vehicles that require fast charging due to business needs, when the electricity quantity is lower than the safety threshold, they should immediately go to the nearest charging station for quick charging.

The basis of OD analysis includes road traffic information, vehicle distribution information and OD matrix information. For a specific traffic area, an OD matrix can be generated to describe the travel rules of large-scale electric vehicles. The OD matrix B consists of
24 sub-matrices $B_{m\times m}^{(t,t+1)}$, where $0 \leq t \leq 23$, and $m$ represents the number of nodes in the area. The matrix element $b_{ij}$ ($1 \leq i \leq m$, $1 \leq j \leq m$) of each sub-matrix represents the number of cars from node i to node j during the period from t to t+1. To facilitate the simulation, $B_{m\times m}^{(t,t+1)}$ will be transformed into $C_{m\times m}^{(t,t+1)}$, where the element $c_{ij}$ of $C_{m\times m}^{(t,t+1)}$ represents the probability of the electric vehicle from node i to node j during the period t to t+1. For the electric vehicles in the "vehicle network road" system, the OD matrix can be used to describe the travel probability of the vehicle in different periods, so as to simulate the driving trajectory of the electric vehicle.

$$c_{ij} = \frac{b_{ij}}{\sum_{j=1}^{m} b_{ij} (1 \leq i \leq m)} \quad (1)$$

The OD matrix provides the driving probability from node i to j, but usually there are multiple roads to choose from between the two nodes. In the simulation, it is assumed that the drivers choose the shortest route during the iterative process of OD analysis. The shortest path $l_{ij}$ between nodes i and j can be obtained by Floyd algorithm. Therefore, the travel time $\Delta t$ from node i to node j can be derived from the formula (2), where $V_{ij}(t)$ is derived from the speed-flow formula according to the road grade.

$$\Delta t = l_{ij} / V_{ij}(t) \quad (2)$$

For electric vehicles using fast charging, the time and space characteristics of fast charging load can be obtained by the following steps:

1. Determine the basic parameters of electric vehicles. Four kind of electric vehicles are selected from the EV MERGE database as taxi simulation samples. The basic parameters are shown in Table 1.

| Manufacturer | Type | Battery | Battery Capacity | Electricity Consumption |
|--------------|------|---------|-----------------|------------------------|
| Audi         | R8   | Lithium battery | 45               | 0.1500                 |
| BMW          | Mini-E | Lithium battery | 35               | 0.2066                 |
| BYD          | E6   | Lithium battery | 48               | 0.1846                 |
| BYD          | E8   | Lithium battery | 72               | 0.1800                 |

2. The initial driving time $t_s$, the initial power $SOC_0$, and the initial position $L_1$ are generated.

3. OD analysis is used to simulate the driving path of electric vehicles. In order to maintain the battery performance, the battery capacity should not be less than 20% of the battery capacity. When the termination condition (3) is satisfied, OD analysis is terminated and the position of electric vehicle at the termination time is recorded.

$$SOC \leq 0.2 \quad (3)$$

4. Determine the space-time information of fast charging. Assuming that the distance from the electric vehicle to the nearest distribution network node k is $d_{or}$, the remaining power during charging and the charging start time $t_{sc}$ can be obtained by (4) and (5) respectively.

$$SOC = 0.2 - d_{or} \cdot \Delta SOC \quad (4)$$

$$t_{sc} = t - d_{or} / V(t) \quad (5)$$

5. Due to differences in the parameters of electric vehicles, the number of fast charging may be more than once in a day. Repeat step (3) to step (4) to get the fast charging time and space information of the same electric car in one day.

For n electric vehicles, the above steps are repeated n times, and the charging time $t_{sc}$ of each vehicle and the node k of the distribution network are recorded, then the fast charging load $P_{ij}(t)$ of node k at time t can be obtained by formula (6), where $m (m=n)$ is the number of electric vehicles that are quickly charged at node k at time t.

$$P_{ij}(t) = \sum_{i=1}^{m} P_{ij}^{k}(t), t = 1, 2, \ldots, 24 \quad (6)$$

For electric vehicles using slow charging, the time and space characteristics of slow charging load can be obtained by the following steps:

1. Generate initial power $SOC_0$

2. Get the travel time $t_s$ and return time $t_f$.

3. Simulate the travel routes of electric vehicles during $t_s$ and $t_f$.

4. Determine the remaining power $SOC_i$ and remaining range $D(SOC_i)$.

5. Determine the starting charging time $t_{sc}$.

Such as (7) formula, when the remaining power is less than the threshold or not enough to support the next driving section, it will be charged immediately. For private cars, $D(n)$ is the shortest path from residence to work; for commercial vehicles, $D(n)$ is the shortest path from the current location to the next destination.

$$SOC_i \leq 0.2 \text{ or } D(SOC_i) < D(n) \quad (7)$$

When the formula (7) is not satisfied, the electric vehicle adopts the intelligent charging method after returning to the initial point O, and the charging time $t_{sc}$ meets the probability distribution of formula (8). Among them, $\mu$ is the average charging start time of residents, and $\sigma$ is the distribution coefficient.

$$f(t_{sc}, \mu, \sigma) = \frac{1}{\sqrt{2\pi \sigma^2}} e^{-\frac{(t_{sc} - \mu)^2}{2\sigma^2}} \quad (8)$$

6. Calculate the slow charge load. From equation (9), the distribution of slow charging load $P_{k}(t)$ at each node can be obtained, where $n (n<n)$ is the number of electric vehicles that are quickly charged at node k at time t.

$$P_{k}(t) = \sum_{i=1}^{n} P_{ij}^{k}(t), t = 1, 2, \ldots, 24 \quad (9)$$

For node k, the total charging load in any period of time can be expressed by equation (10).

$$P_k(t) = P_{ij}(t) + P_{k}(t), t = 1, 2, \ldots, 24 \quad (10)$$

Table 1. Basic parameters of four kinds of electric vehicles.
5 The impact of electric vehicles on renewable energy

Because renewable energy has the characteristics of randomness, intermittent, when it is integrated into a large power grid, it is easy to cause problems such as grid voltage deviation, voltage fluctuation and flicker, frequency deviation, harmonic, and DC injection. Firstly, the orderly access of electric vehicles will improve the ability of the power system to absorb fluctuant renewable energy, reduce the amount of wind and photovoltaic abandonment, and reduce the cost of power generation and the level of pollutants and carbon emissions; Secondly, the orderly guidance of the charging load of electric vehicles will reduce the load peak and off-peak difference of the power system, improve the operating efficiency of generator, and save power generation capacity investment and fuel costs; Thirdly, the flexible charging and discharging of electric vehicles can be used as ancillary service resources in power system, reducing the cost of auxiliary services. Fourthly, effective management of electric vehicle charging will avoid or delay transmission and distribution investment costs to a certain extent.

If electric vehicle charging is not managed or guided, the charging load of electric vehicles will not help the grid-connected consumption of renewable energy, but will increase the peak regulating pressure of the power system, which will intensify the problem of renewable energy curtailment. If grid-connected methods such as orderly charging, two-way interaction between vehicles and the grid (V2G), and decommissioned battery energy storage are adopted, the energy storage potential of electric vehicles can be fully released, and the power system's ability to absorb renewable energy will be significantly improved.

At present, the trading modes of electric vehicles, distributed generation, energy storage, etc. participating in the power market at home and abroad can be summarized as the following several figures.

6 Conclusion

With the increasing number of electric vehicles in China,
it will be a challenging task to realize the orderly charging of electric vehicles. Fully exploiting the energy storage advantages of electric vehicles is of great strategic significance for power system transformation. Therefore, first of all, according to the charging characteristics and operation mode of electric vehicles, it is necessary to upgrade the distribution network, realize the technical adjustable and controllable, and gradually improve the top-level design of intelligent electric grid. Secondly, from the perspective of policy, we should build a competitive platform in the electricity market and give full play to the real-time charging and discharging pricing mechanism. Finally, the status of electric vehicles in the load resources should be clarified, its energy storage characteristics should be mobilized, and the natural advantages of V2G or the load aggregator agents should be involved through demand side response to improve the power grid's ability to absorb renewable energy.

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