Optimization of New Energy Consumption Strategy for Electric Vehicles Based on Vehicle Networking

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Abstract

In order to curb global warming, the country vigorously develops new energy, but the current problem of mismatch between the scale of new energy and local consumption market in China aggravates the contradiction of new energy consumption. In order to alleviate the scarcity of flexible regulation resources brought by the development of high proportion of renewable energy, this paper explores the transfer-ability of EV charging load in terms of EV starting charge state, EV users' daily driving mileage pattern and charging time preference; and explores the correlation between EV load and new energy output by combining the characteristics of new energy output. On this basis, the paper proposes a centralized regulation method to shift the charging time of EV users to the time when the new energy is not sufficient to improve the system's ability to absorb intermittent new energy.

Keywords: *Electric vehicles, Centralized regulation; New energy consumption*

1. INTRODUCTION

At present, China has the largest number of new energy vehicles in the world. Telematics technology makes the interaction between electric vehicles and the grid easier, and the large number of electric vehicles reduces greenhouse gas emissions, which is conducive to China's achievement of the 2060 carbon neutrality target, and can also alleviate to a certain extent the current high proportion of renewable energy development brings new energy consumption carrying pressure to the grid.

Recently, scholars have conducted many studies on new energy consumption. In the literature [1], a load aggregator and wind farm co-operative operation model is proposed, in which the load aggregator acquires the abandoned wind power at a lower price than the power purchased from the grid, and uses the load under the jurisdiction of the load aggregator to improve the level of wind power consumption. In the paper [2], a multi-objective wind power consumption model is established to promote wind power consumption and profitability for both source, network and load participants by adjusting customer electricity consumption with a time-sharing tariff mechanism. The paper [3] analyzed the operational characteristics of large-scale wind power connection to the grid and the reasons for blocked wind power consumption, and explored the feasibility of electric vehicle load participation in regulation for blocked wind power consumption. The literature [4] explored the spatio-temporal complementary characteristics between multiple energy sources and established a multi-energy power system source-load coordination two-tier dispatch model to improve the level of dissipation.

The operation mechanism of a power system with a high proportion of renewable energy sources on the grid requires more flexibility and requires a flexible resource supply-demand balance as the core to achieve grid security and stability. In the context of vehicle networking, giving full play to the regulation ability and value of electric vehicle load is conducive to improving the level of green energy consumption and operational efficiency of the grid. According to the main charging periods of EVs and their load shifting ability, the system will be shifted to the periods with insufficient new energy

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consumption to improve the absorption ability of intermittent new energy.

2. ELECTRIC VEHICLE LOAD CHARACTERISTICS

2.1. Electric vehicle starting charge state

SOC is commonly used to indicate the state of charge, i.e. the ratio of the remaining capacity of a battery to its total available capacity after a period of use or long-term shelving.

$$SOC = \frac{Q_{\text{remain}}}{Q} \times 100\% \tag{1}$$

where Q_{remain} is the remaining battery capacity and Q is the total available capacity.

Assuming that the electric vehicle is charged/discharged with a constant current I and the charging/discharging efficiency of the electric vehicle is η, SOC_0 is the state of charge after the electric vehicle is fully charged, then the state of charge SOC of the electric vehicle can also be expressed as:

$$SOC = SOC_0 - \eta \times \frac{\int Idt}{Q} \times 100\% \tag{2}$$

At this time, use $I > 0$ indicates that the electric vehicle is in the discharge state;use $I < 0$ indicates that the electric vehicle is in the charging state.

2.2. Electric vehicle users' daily mileage pattern

Users' travel habits and their work driving characteristics determine their daily mileage, and in recent studies, the average daily mileage of EV rental passenger cars is as high as 232 km/day, and 165 km/day for buses and coaches; the average daily mileage of private passenger cars is 65 km/day, business passenger cars is 97 km/day, logistics special vehicles is 90 km/day, and rental passenger cars is 123 km/day. And a few private passenger cars are idle, and after scholars' research, the daily mileage of electric vehicle users can be regarded as a lognormal distribution model[5] or an exponential distribution model[6]. From a practical point of view, both very close trips and very long trips of EV users are small probability events, so the log-normal distribution model is used to better reflect this daily mileage pattern.

$$f(s) = \frac{\exp[-\frac{(\ln s - u)^2}{2\sigma^2}]}{\sqrt{2\pi}\sigma s} \quad 0<s<300 \tag{3}$$

Where, s is the daily mileage of electric vehicle users, in kilometers, μ and σ are the mean and standard deviation of daily mileage, respectively.

2.3. Electric vehicle charging time preference

The EV charging time can be estimated according to the travel needs of EV users and the state of charge.

$$T = \frac{(SOC_{end} - SOC_{start}) \times Q}{\eta P} \tag{4}$$

Where, SOC_{end} is the charge state at the end of charging, SOC_{start} is the charge state at the beginning of charging, and the charging power P is assumed to be constant. The flexible charging times of different types of electric vehicles are shown in Table 1.

TABLE 1. ELECTRIC VEHICLE CHARGING HOURS

Electric Vehicle Category	Flexible charging time
Private Car	The peak travel times for users on weekdays are 7:00~8:00 and 17:00~19:00, while other times are more flexible and can be charged at any time.
Buses	The bus starts running at about 5:00~6:30 and stops running at 22:00~23:00. Since the bus can only be charged at the departure station, the flexible charging period for the bus is 23:00~5:00.
Cabs	The daily mileage is large, and drivers basically use their break time to charge their electric vehicles: 6:00~7:00, 11:30~14:00, and 16:30~17:30.
Official Cars	Its use is mostly during working hours from 9:00 to 18:00, and other times can be flexibly arranged for charging.

2.4. Transferable capacity of charging load

With the technical support of Telematics, the grid side can transmit the information of the insufficient time of new energy consumption to the electric vehicle user side through the system platform, so that the user will gradually shift the charging time to the insufficient time of renewable energy consumption under the attraction of corresponding preferential policies and on the premise of meeting the travel requirements.

$$P_{t,after} = P_{t,before} + \sum_{n=1}^{N} \sum_{t=1}^{T} (\alpha_{n,t} - \beta_{n,t}) \Delta P_{n,t} \tag{5}$$

where $P_{t,before}$ and $P_{t,after}$ denote the power consumption values of the transferable load of the electric vehicle before and after the transfer, respectively; $\alpha_{n,t}$ and $\beta_{n,t}$ denote the state of the load transfer in and out of the nth type of electric vehicle at moment t. Setting them as 0-1 variables, if the load is transferred in at moment t, then $\alpha_{n,t}=1,\beta_{n,t}=0$. $\Delta P_{n,t}$ is the transfer power value of the transferable load n at time t. .

3. NEW ENERGY OUTPUT CHARACTERISTICS

3.1. Seasonal characteristics

China's "three north" area new energy centralized large-scale development, rapid growth in power generation, but the scale of new energy and the local consumption market serious mismatch, intensifying the contradictions of new energy consumption. And wind power, solar energy and other renewable energy volatility factors make the power system security and stability is low. To alleviate this symptom, the "Thirteenth Five-Year Plan" period, the state efforts to promote the optimization of wind power industry layout, promote the development of photovoltaic industry, the annual utilization hours of wind power from 1728 hours in 2015 to 2097 hours in 2020; 2020 China's photovoltaic power generation utilization hours, the northeast region 1492 hours ranked First.

The average monthly output of wind power generation varies from month to month, generally from October to February, the average monthly output of wind power generation is larger, and the average monthly output of wind power generation is smaller in June and July every year. Due to the intensity of sunshine, the average monthly output of photovoltaic power generation is larger in summer and smaller in autumn and winter.

3.2. Daily Characteristics

Photovoltaic power generation activities are carried out from 5:00 to 20:00, and stop at night time. Due to the periodicity of sunshine intensity and time change, the peak size of daily maximum output distribution has seasonal difference, and the peak time of PV daily output is concentrated between 11:00-13:00; wind power output has certain anti-peak regulation characteristics. The average power output of wind power is larger in the evening 20:00-07:00, and smaller in 09:00-18:00.

4. THE CORRELATION BETWEEN ELECTRIC VEHICLE LOAD AND NEW ENERGY OUTPUT

4.1. Electric vehicle load curve

A total of 24 hours a day, according to 15 minutes a step, the 24 hours into 96 time points, and the daily real-time load of electric vehicle rental passenger car, bus, private passenger car, business passenger car, logistics special vehicle, rental passenger car, etc. summed up to get the total load curve of electric vehicles as shown in Figure 1.

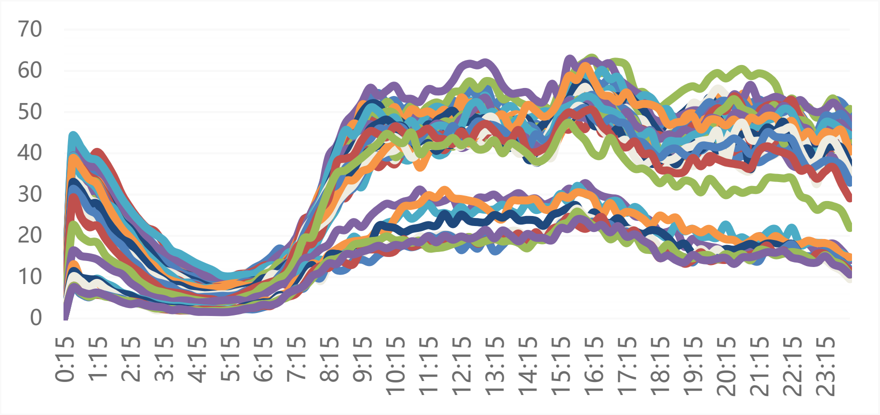

Figure 1. Total load curve of electric vehicles

4.2. New energy output curve

From Figure 2, we can see that PV output is concentrated in the noon time, while wind power output is smaller in the noon time, but considering the seasonal and weather factors, wind power output may be on the rise in the noon time, so microscopically wind power and PV output have weak complementarity.

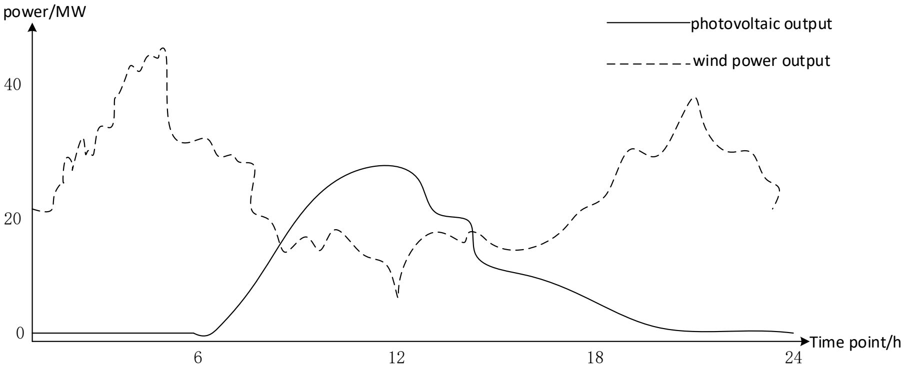

Figure 2. Wind and light output curve

4.3. Correlation analysis

Pearson correlation analysis is conducted between the total load data of electric vehicles in a region for 5 consecutive days and the time point, wind power output, photovoltaic output and total output of wind and solar power generation respectively. Double tail test is adopted. The correlation of each combination shown in Table 2 is significant at 0.01 level.From the results, it can be seen that due to the anti-peak characteristics of wind power output, it has a negative correlation with EV load, and the correlation between total wind power output and EV load is around 0.6.

Table 2. Correlation analysis

Relevance	D1	D2	D3	D4	D5
Point in time	0.649	0.718	0.696	0.68	0.662
Wind power output	-0.448	-0.392	-0.414	-0.429	-0.467
Photovoltaic power output	0.683	0.638	0.669	0.669	0.713
Total Effort	0.627	0.627	0.651	0.628	0.654

5. JOINT OPTIMIZATION OF CONSUMPTION STRATEGY

5.1. Distribution autonomy

With the rapid development of flexible demand-side resources represented by electric vehicles, large-scale, disorderly demand-side resources will have an impact on the operation of the power system, home electric vehicles occupy a large proportion of electric vehicle ownership, however, because the time of household electric vehicles connected to the charging pile is just in the peak period of the power grid, charging immediately after the access will inevitably make the power grid "peak on peak". At this time, the reasonable use of peak and valley tariffs, with the help of price leverage, can guide users to change the original way of using electricity and improve the impact on the grid. However, it is difficult to obtain the new energy consumption demand of the grid side at different time periods, plus the randomness and uncertainty of the electric vehicle user's independent response, which may cause lagging response or over-response, which largely limits the accuracy and timeliness of the demand-side response and cannot guarantee the effect of regulation and consumption.

5.2. Centralized regulation and control

The Internet of electric vehicles uses big data, cloud computing, Internet of things, mobile Internet, artificial intelligence and other technologies to realize the access monitoring of offline service resources such as charging piles and electric vehicles,with functions such as resource monitoring, business operation, charging service, leasing service and value-added service to meet flexible resources supply and flexible scheduling. Load aggregators help electric vehicle users transfer the charging period to the period of insufficient new energy consumption according to the main charging period and load transfer capacity of electric vehicle The electric energy storage capacity of EV charging battery and the transferable capacity of charging load may provide high quality power regulation resources for new energy access to the system and improve the system's ability to absorb intermittent new energy. The centralized regulation mode is conducive to reducing the uncertainty and randomness of EV user-side resources, and at the same time, it can enhance the system regulation capacity and improve the renewable energy absorption capacity. The charging load aggregators aggregate the electricity of electric vehicle users to participate in the electricity market, alleviating the "peak on peak" and improving the safety and stability of system operation; reducing carbon emissions in the process of electricity production and conversion, improving energy utilization efficiency, and promoting energy conservation and environmental protection.

6. CONCLUSION

In order to adapt to the intermittent and fluctuating power supply of new energy and to ensure safe and reliable power supply, a certain proportion of flexible regulation power must be allocated as an important support. The massive popularity of electric vehicles provides the feasibility of smoothing out the fluctuation of new energy, and the aggregation of electric vehicle loads is an effective solution. The electric energy storage capacity of electric vehicle charging batteries and the transferable capacity of charging loads have the potential to provide high-quality power regulation resources for new energy access systems and improve the system's ability to absorb intermittent new energy. In this paper, we study the characteristics of EV load, green energy power output and the correlation between EV load and new energy output, and propose to shift the charging time of EV users to the time of insufficient new energy consumption by using centralized regulation based on vehicle networking technology, and establish the joint optimal consumption strategy of vehicle networking and green energy.

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