Application of PV- Storage System in Typical Industrial Users

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Abstract. The power consumption of industrial enterprises is characterized by large power consumption and high reliability requirement, so the cost of electricity consumption is relatively high. Distributed photovoltaic power generation is clean and environmentally friendly, making full use of the roof area to generate electricity. Based on the characteristics of distributed photovoltaic and energy storage, this paper constructs the distributed optical storage model and operation strategy. In addition, this paper takes an industry as an example to carry out relevant verification and analysis.

1 Introduction

At present, China's economy has shifted from a stage of rapid growth to a stage of high-quality development. The efficient use of resources, technological progress and institutional innovation have increasingly become important driving forces for industrial transformation and upgrading and sustainable economic and social development. High-quality development of energy is crucial to the China's economy. It is imperative to build a clean, low-carbon, safe and efficient modern energy system. Distributed photovoltaic is suitable for installation on the roofs of industrial parks, economic development zones, large industrial and mining enterprises, shopping malls, schools, hospitals and other public buildings. Its advantages lie in its proximity to users and its low cost. In addition, rooftop photovoltaic can play an insulating role, which can save electricity and generate electricity. In the future, more new installations will depend on distributed photovoltaic to achieve [1]. Distributed photovoltaic generally refers to photovoltaic power generation system with a capacity of no more than 6 MW, which is added to the grid at voltage level of 10 kV or below [2].

The main functions of energy storage system in user-end distributed power generation are peak load cutting, smooth output, tracking planned output, and supporting safe and stable operation of power grid [3]. As a typical type of load with high energy consumption, industrial users use a large amount of electricity, which requires a high reliability of power supply. Moreover, the peak price of electricity price coincides with the peak value of load, leading to a high cost of electricity for industrial users. If the energy storage battery can be used to store the electric energy from the peak period to the peak period, it will reduce the peak purchase power of industrial users, thus reducing the cost of electricity for enterprises.

2 Characteristic analysis

2.1. Peak-valley pricing mechanism

FIG.1 shows the difference of peak and valley electricity price in some provinces. It can be seen that the commercial or large industrial electricity consumption exceeds 0.7 yuan/kWh, which means that the above areas have relatively good conditions for carrying out user-side energy storage in Beijing, Jiangsu, Guangdong, Zhejiang, Gansu, Henan, Anhui, Yunnan, Shanghai and other 9 provinces and cities. In addition, it provides the user side of energy storage in these areas is more favourable conditions.

Figure1 the difference of peak and valley electricity price between general industry and large industry in some provinces

2.2 PV output characteristic

Distributed photovoltaic output is intermittent and highly random, which is not only affected by climatic and environmental conditions such as illumination and season, as well as objective operating conditions such as geography and time, but also restricted by adjacent

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photovoltaic and power loads that are connected to each other. In order to effectively reduce the influence of its volatility on the operation stability of distribution network, domestic and foreign scholars have studied its characteristics. Literature [5] and literature [6] analysed the probability distribution characteristics of photovoltaic output on several typical days in different seasons. FIG. 2 shows a distributed photovoltaic with an installed capacity of 500kw. The daily PV output curve of no output period at night is removed in typical sunny, rainy, cloudy and rainy weather conditions.

Generally, distributed photovoltaic power starts to increase at 6:00 am, reaches the peak from 11:00 to 13:00 at noon, and then gradually declines, and almost drops to zero from 17:00 to 18:00 in the afternoon. Generally, most of the maximum output time of distributed photovoltaic power falls between 11:00 and 13:00.

Figure 2 PV output distribution under different weather conditions

2.3 Characteristics of energy storage system

Energy storage system generally includes battery, two-way energy storage converter and corresponding energy management system. According to the output of photovoltaic power generation system and the change of industrial load, the energy storage system has three states: charging state, discharging state and static state. As a storage device of energy, battery can convert electric energy into chemical energy when charging, and release the stored electric energy through electrochemical reaction when discharging. This electrochemical conversion process is reversible, and there will be a certain amount of energy loss in this process. The charging and discharging efficiency of battery is usually expressed by energy efficiency. The energy efficiency of a battery is the ratio of the energy output of the battery when discharging to the energy input when charging. At present, the charging and discharging efficiency of lithium iron phosphate battery reaches 95%, and at the present stage, lithium iron phosphate battery has technical and economic advantages in the early stage of commercialization [7].

2.4 The operation strategy of PV-storage system

Distributed optical storage system consists of photovoltaic array, photovoltaic inverter, energy storage battery pack, energy storage inverter, distribution

network, energy management system, load and other parts. Distributed photovoltaic energy storage and power generation system can store excess power generation and increase the proportion of spontaneous and self-use. It is usually applied in application places such as photovoltaic spontaneous and self-use with no surplus online, high electricity price for self-use and large difference between peak and valley electricity price. The photovoltaic array converts the solar energy into electric energy under the light, and then power the load or charge the energy storage battery pack through the photovoltaic inverter.

In addition, during the peak period of electricity price, the energy storage battery will supply power to the ac load through the energy storage inverter. Distributed optical storage system, on the one hand, users photovoltaic modules to generate electricity, helping users to reduce electricity consumption or electricity bill; On the other hand, energy storage batteries charge in the trough period and discharge in the peak period, making money by using the peak-valley price difference. Finally, when the power grid is cut off, photovoltaic and energy storage battery can continue to work as backup power supply to supply power to inverter load and ensure the reliability of power supply to users.

Figure 3 Distributed optical storage system

Based on load characteristics, energy storage characteristics and peak-valley electricity pricing mechanism of industrial users, this paper formulated the following operation strategies of distributed optical storage system.

The output power of the photovoltaic system is greater than the load of industrial users:

1) When the peak period is reached, photovoltaic power will be provided to industrial users first. If the battery is not fully charged, the excess electric energy will be charged to the energy storage battery first.

2) When it is in a flat period, the battery does not need to be charged and discharged, and the excess electric energy will be supplied to the large power grid in a reverse flow.

3) When it is in the valley period, the distribution network and photovoltaic will charge the battery at the same time. If the battery is full, the excess electric energy will be used to supply power to the large grid.

The output power of photovoltaic system is less than the load of industrial users:

1) During the peak period, the photovoltaic power generation and battery power supply all supply industrial

users. If the power cannot meet the user load, the power supply shall be provided by the distribution network.

2) When it is in the parity period, the battery has no charging and releasing process, and the insufficient load of the same household is supplied by the distribution network.

3) When in the valley value period, the distribution network provides power to both battery and user load.

2.5 Revenue composition of distributed optical storage system

After the configuration of the optical storage system, the main revenue sources are divided into two categories, including B_{pv} from reducing the amount of electricity purchased by industrial users from the distribution network due to the use of photovoltaic power generation, and B_{BESS} from reducing the peak electricity price when the energy storage system releases the amount of electricity stored in the valley period at the peak period [8].

$$B = B_{pv} + B_{BESS}$$

Photovoltaic system revenue B_{pv} includes three parts: photovoltaic power generation government subsidy, photovoltaic self-use revenue and reverse grid power supply revenue.

$$B_{pv} = \sum_{t=0}^T [P_{pv}(t)V_b + P_{pv1}(t)V_1(t) + P_{pv2}(t)V_2(t)]\Delta t$$

Where $P_{pv}(t)$, $P_{pv1}(t)$, $P_{pv2}(t)$ Represents the power of photovoltaic power generation system, the power supplied by the photovoltaic system to the user, and the power supplied by the photovoltaic system to the grid, respectively; V_b , $V_1(t)$, $V_2(t)$ Respectively represents the government subsidy price for photovoltaic, electricity price for users, and electricity price for photovoltaic power grid. T Represents the typical daily length.

The energy storage benefits are mainly obtained from the storage of excess power of the photovoltaic system and the supply of electricity to users during the peak period of the off-peak period of charging, which can be expressed as follows:

$$B_{BESS} = \sum_{t=0}^T [E_{pv}(t) + E_{BESS,1}(t)V_3(t) + P_{BESS-1}(t)V_4(t)]\Delta t$$

Where $E_{pv}(t)$, $E_{BESS,1}$, $V_3(t)$, $V_4(t)$ Do not indicate the amount of photovoltaic charge to energy storage, the amount of grid charge to energy storage battery in the trough period, the peak price of electricity and the valley price of electricity.

3 Case study of an industry

3.1 Basic data

This paper takes an industrial user in Zhejiang province as an example. FIG. 4 shows the typical daily load change curve of the industrial park, with the average daily load of about 2.05mw. In addition, the load curve

presents a high distribution in the day and a low distribution at night. The peak load occurs between 14:00 and 21:00 in the afternoon, and the difference between peak load and valley load is about 1MW, so the typical daily electricity consumption is about 49MWh. In addition, according to statistics, the plant roof area of the park is about 40000m².

Figure 4 Typical daily electric load curve

The voltage level of the park is 20kV. According to relevant regulations, the electricity price in the industrial park is 0.4004 yuan /kWh in the trough, 0.8771 yuan /kWh in the peak, 1.0571 yuan /kWh in the peak, and 0.6567 yuan /kWh in the peak and valley. Among them, daily 19:00 -- 21:00 refers to peak electricity price period; 22:00 -- 8:00 the next day and 11:00 -- 13:00 refer to trough electricity price period; 8:00 -- 11:00, 13:00 -- 19:00 and 21:00 -- 22:00 refer to peak electricity price period.

3.2 Basic data

According to the roof area of the industrial park and the related layout requirements of photovoltaic modules, polycrystalline 280Wp modules are selected in this paper, and the inclination Angle of photovoltaic modules is set at 15°. However, due to the complex roof environment and low efficiency, distributed photovoltaic modules with a total capacity of 1.1386mwp can be built on the roof of the plant. According to the analysis, since the park is newly built and has a large transformer capacity, the benefit of energy storage system in reducing the capacity of electricity is not considered. At present, the maximum demand of transformer in the park is 3MW, so it is necessary to try not to increase the demand after energy storage is connected, and maintain the same demand of transformer. Considering comprehensively, 500kW/1MWh lithium iron phosphate energy storage system is configured to achieve the energy storage effect of 2h.

In this case, the output power of the photovoltaic system is less than the power load of the industrial park, so all the power generated by the rooftop photovoltaic system is supplied to the industrial park. According to FIG.5, after the adoption of the photovoltaic system, the power purchased by industrial users from the grid during the period of photovoltaic power generation is significantly reduced.

The energy storage system adopts the charge and discharge mode of two charges and two puts. The first constant power charge (charge and discharge efficiency is calculated at 95%) is carried out in the night valley power period; the constant power discharge (95%DOD) is carried out in the peak electricity price period from 8:00 to 11:00; the second constant power charge is carried out in the valley power period from 11:00 to 13:00; and the constant power discharge is carried out in the peak electricity price period from 19:00 to 21:00. Under 95%DOD mode, the charge and discharge cycle life of lithium iron phosphate energy storage battery is about 5000 times, and the annual loss of energy storage battery during the cycle life is 2%.

Figure 5 Industrial load curve

Pvsyste software simulation results show that the average annual power generation of the plant roof photovoltaic arrangement capacity in this park is about 137.16 (10,000 •kWh) for 25 years, and the annual equivalent utilization hours are about 989.58 hours. If the electricity price in the industrial park is calculated at 0.63875 yuan /kWh on average during the period of photovoltaic power generation, it is estimated that the photovoltaic system can earn 876,100 yuan per year. The energy storage system can adopt the charge and discharge mode of two charges - discharge modes. Considering the maintenance and rest time, it is estimated that the energy storage system can earn 340,200 yuan per year if the working day of the energy storage system is 300d per year. To sum up, if the above-mentioned light-storage system scheme is adopted, the annual income of the industrial park can reach 1216.12 million yuan.

Conclusion

Loads for industrial user are characterized by large power consumption, large scale and extremely high power supply reliability requirements. Therefore, industrial users not only invest a lot in electricity consumption, but also consume a large amount of primary energy to produce such electricity, which causes pollution to the environment. We should try to change this way of generating electricity through distributed photovoltaic systems.

Distributed optical storage system can not only use photovoltaic modules to generate electricity and reduce the amount of electricity purchased by industrial users from large power grid, but also use the energy storage system to charge during the valley value period and discharge during the peak period, making money by taking advantage of the difference between peak and valley electricity prices. According to the calculation results, the annual income of a science and technology industrial park after adopting the optical storage system can reach 1216.12 million yuan, contributing to the cost reduction and efficiency of enterprises and the green and harmonious development of society.

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