Research on the Application of Renewable Energy in DC Data Center

Xingyu Bai
Chengdu University of Information Technology
No.24, Section 1 of Xuefu Road, Southwest Airport Economic Development Zone,
Chengdu, Sichuan
2628569415@qq.com

Abstract- With the rapid development of the information technology industry, the demand for data centers is gradually expanding. As the foundation of carrying many information technology services, data centers have been built and put into use on a large scale. At the same time, the characteristics of huge energy consumption are more obvious. Due to the defects of low utilization rate, heavy pollution and limited reserves of traditional fossil fuels when supplying energy for data centers, the development of green renewable energy has become an inevitable demand. This paper studies the key technologies involved in supplying power to DC power supply data center with renewable energy, and makes a case to compare the DC power supply system and the AC power supply system. This paper also pays attention to the technology of energy storage in data center, and makes an analysis to prove the advantages of energy storage data center. In addition, this paper studies and summarizes the application of multi-station integration technology and other issues.

1. Introduction
Developing green data center is an important part of national strategy, technological development and social life. The energy consumption of data center is huge, and the annual economic input cost is very high. The data shows that the total power consumption of China's data centers in 2017 exceeded 120 billion kWh, exceeding the sum of the annual power generation of the Three Gorges Dam and the power generation of Gezhouba Power Plant in the same year. In 2020, the number of data centers in China has exceeded 80,000, with a total area of over 30 million square meters. Correspondingly, the energy consumption is also increasing year by year. Therefore, it is a major problem to be solved to study the appropriate energy supply scheme and promote the green development of data centers.

The traditional power supply mode uses UPS, but its efficiency is low, energy consumption is high and economy is poor relatively. Thus, a new technology represented by DC power supply mode is born. The DC control and protection system is mainly in the form of industrial computer [1], which has entered the stage of large-scale application in China.

In view of the high energy consumption, heavy energy pollution and existing problems in the original data center power supply mode, this paper analyzes the application and development of renewable energy, DC power supply technology and energy storage technology in the data center. Literature [2] introduces the application of renewable energy in data center. Literature [3] lists the huge energy consumption data of the data center, which shows the necessity and urgency of using renewable energy to power the data center. Literature [4] is a summary of the application of energy
storage technology in renewable energy systems. Literature [5] pointed out the requirement of equipping data centers with energy storage, specifically pointed out the defects of traditional power standby mode, and put forward an energy storage data center. Literature [6] introduces the application of lithium battery for energy storage systems. Literature [7] puts forward the concept of ‘5G-source network-load storage’ multi-station integration which mainly focusing on digital services and energy services. Literature [8] proposes a distributed coordination control strategy for load sharing and energy balancing between heterogeneous energy storages. Literature [9] evaluates the long-term impact of grid level energy storage on the penetration of solar and wind energies and on CO2 emissions reduction in Chile.

2. Renewable energy application in data center

2.1 Application of renewable energy

For a long time, fossil energy, as the main power generation source, has been applied in the power supply of data centers. Fossil energy such as oil, natural gas and coal account for about 86% of the total energy consumption in the world. However, fossil energy has caused serious pollution to the global environment. Long-term use of fossil energy will bring many irreversible harms to human society and face the risk of energy depletion. Therefore, this paper studies the application prospect and technical methods of renewable energy for data center power supply.

Renewable energy is widely used in power generation, especially in data centers [2]. The report shows that as early as 2015, the power consumption of big data centers nationwide has reached 100 billion kWh, which is equivalent to the annual power generation of the Three Gorges Power Station. In 2018, this figure reached 160.9 billion kWh, exceeding the annual social electricity consumption in Shanghai. It is estimated that by 2030, global big data centers will consume about 30% of the world's electricity [3]. The energy consumption of data centers is very high. In order to achieve the common goals of saving energy, reducing pollution and protecting the ecological environment, the world's leading technology companies have joined the RE100 organization and advocated the vigorous use of renewable energy.

2.2 Application of Energy Storage Technology in Data Center

2.2.1 Energy storage technology in data center

In recent years, the development of energy storage has been widely reported. Facing the problem of huge energy consumption in data centers, energy storage is an important means to effectively reduce energy consumption, save energy and reduce emissions, and is applied to the construction and development of data centers [4].

There are many types of energy storage technologies, which can be divided into gaseous energy storage (air compression, hydrogen energy), liquid energy storage (pumped energy storage, photo-thermal liquid oil), solid energy storage (battery, capacitor), etc. It can be divided into physical energy storage (flywheel energy storage), electrochemical energy storage (batterie) and electromagnetic energy storage (superconducting energy storage). Among them, electrochemical energy storage technology is widely used in data centers. Energy storage technology plays a very important role in energy transformation. Its application degree not only determines the development level of renewable energy, but also determines the success or failure of data center construction and development.

Traditional data center power backup system consists of UPS host and lead-acid battery. When the mains supply is normal, UPS supplies power to the load after filtering the mains impurities, and charges the battery at the same time. When the mains is abnormal (power supply is interrupted), the battery is discharged and supplied to the load through UPS to ensure power supply [5].

Thanks to the development of energy storage technology in recent years, the construction of energy storage data center has become an important means to solve the above problems.
The traditional energy storage form of data center is lead-acid battery, which has stable voltage and low price. It has been used and developed for more than 100 years, but it is short in service life, easy to collapse instantaneously, pollutes the environment and has high demand for maintenance. In order to improve the security of the power supply system of the data center computer room, the operators of the data center computer room gradually use lithium batteries to replace the traditional storage batteries, so as to better realize the modernization process of the data center computer room industry [6]. At present, the purchase cost of lithium iron phosphate battery is higher than that of lead-acid battery, which is about 1.5 ~ 3 times that of lead-acid battery. However, due to its advantages of long service life, low maintenance cost and high working efficiency, it can save the total cost in the long run.

2.2.2 New application of energy storage in data center

The introduction of energy storage technology in the data center has the following advantages compared with the traditional backup power supply in the data center:

(1) The battery investment can be recovered by peak shaving and valley filling mode. Taking a UPS with a power of 500kW and a power factor of 0.8 as an example, for convenience of calculation, the discharge parameters of Siendi SHC12 250FT battery are adopted, the battery price is 1 CNY/Wh, the electricity price difference is 0.78 CNY as a reference, and the residual value of the battery is calculated by 25%. 120 SHC12 250FT batteries are required for standby power of 500kW UPS for 15min. Assuming that three more batteries are added, the discharge depth is 50% DOD, and the battery is used for 10 years. The preliminary income is calculated as shown in Table 1:

Table 1 10-year revenue estimation of data center with energy storage technology

|                                      | Traditional UPS | Energy storage UPS |
|--------------------------------------|-----------------|--------------------|
| Number of batteries connected in series (AH/group) | 40              | 40                 |
| Number of parallel battery groups (groups)   | 3               | 6                  |
| Total battery capacity (kWh)             | 288             | 576                |
| Battery price (CNY/AH)                  | 2400            | 2400               |
| Discharge depth of battery.              | 50%             |                    |
| Battery life (times)                    |                 | 3600               |
| Total battery price (CNY)               | 288,000         | 576,000            |
| Peak-valley electricity price difference (CNY/kWh) | 0.78          | 0.78               |
| Peak-valley arbitrage in life cycle (CNY) |                 | 808,704            |
| Residual value of battery (CNY)          |                 | 144,000            |
| Total income in life cycle (CNY)         |                 | 376,704            |

It can be seen from the table that transforming the traditional UPS power supply into the energy storage UPS voltage can not only recover the battery investment, but also obtain a large amount of benefits during the battery life cycle, thus greatly saving the cost of the data center.

(2) The battery is discharged every day, and the health state of the battery can be known through the cut-off voltage after discharge. It is helpful to eliminate bad batteries in time, and at the same time, it also saves the cost of doing false load test every year. However, batteries in traditional data centers are rarely discharged, and the state of batteries is unknown.
(3) The standby time of data center is longer. Because more batteries should be configured, the standby time of batteries under the same power is much longer than that of conventional configuration. Besides, the energy storage data center should be built in a place with peak-valley price difference, and the larger the peak-valley price difference, the better the income will be. In addition, the factors affecting the installation area should also be considered.

2.3 System design based on application of renewable energy in DC data center

2.3.1 Case analysis
Taking an 8kW data equipment as an example, there has a concrete comparative analysis between the high voltage DC power supply system and the UPS power supply system. It can be seen that every 8kW of data equipment adopts high voltage DC power supply system, which saves 42,398 kWh of electricity every year, and the power saving rate is about 25.3%. In the case cited in this paper, the total power consumption of data equipment in a data center computer room is 16000kW, and the annual power saving is about 84.8 million kWh. According to the price of 1 CNY/kWh, the electricity cost can be saved by 848,000,000 CNY a year. If combined with the construction scheme of 'multi-station integration', self-built photovoltaic sub-station can lower the electricity cost than the ordinary case, and if the price of 0.7 CNY/kWh is adopted, the annual energy-saving electricity cost can be about 593,600,000 CNY. After the introduction of 'multi-station integration' mode, although the difference in electricity consumption between UPS system and high voltage DC system is reduced, the electricity consumption of both systems is lower than that of the original photovoltaic substation, and the electricity consumption of high voltage DC system is always lower than that of UPS system.

Table 2 Comparison of energy expenditure between UPS power supply system and high-voltage DC power supply system

| Power consumption (kW) | UPS power supply system | high voltage dc power supply system | remarks |
|------------------------|------------------------|------------------------------------|---------|
| Data power consumption | 8                      | 8                                  |         |
| Loss of rectifier cabinet in data center | 3.33 | 1.36 | UPS power supply efficiency is 75%, and high voltage DC is 88%.
| System rectification loss | 2.35 | 0.86 | UPS power supply efficiency is 85%, and high voltage DC is 93%.
| System input power consumption | 13.68 | 10.22 | |
| Air conditioning power consumption | 5.47 | 4.09 | The air conditioning power consumption is 40% of the system input power consumption. |
| add up to | 19.15 | 14.31 | |
| Energy consumption for 1 year | 167754 | 125356 | |

3. Key technologies for future development

3.1 Multi-station integration technology
'Multi-station integration' mode is an important development mode in the construction of data center, and also an important application of power Internet of Things. 'Multi-station integration' is based on the existing substation resources, and uses the data integration center to build various substations such as charging and replacing power plants, energy storage stations, 5G base stations, photovoltaic power stations, wind power stations, etc., which can
expand the value of power Internet of Things at a deeper level from the existing value of substations. The energy storage station, as a backup energy station, can realize the business functions of peak shaving and frequency modulation and renewable energy consumption, and can also reduce the electricity cost of data center operation. Under the peak-valley electricity price policy, shifting the power consumption of the data center from peak hours to peak hours can save more electricity bills. Energy storage station can also reduce the peak load of charging and distribution capacity, and improve the utilization rate of equipment. Figure 1 is a schematic diagram of 'multi-station integration' mode.

Fig.1  Schematic diagram of 'Multi-station Convergence'

The 'multi-station integration' architecture of full DC bus is a practical architecture. At present, the high integration of energy storage stations, new energy substations, substations and data centers can be realized through full DC. The system architecture is shown in Figure 2. On the power supply side, 10kV commercial power is rectified and connected to DC buses 1 and 2, with circuit breakers. The new energy substations are directly connected to DC buses 1 and 2 through inverters and circuit breakers, and a contact switch S1 is provided between the two buses. At the distribution end, the energy storage station and data center are connected to two buses through chopper, loop switch control equipment and loop switch. Compared with traditional discrete systems, this architecture can provide large-scale new energy consumption, reduce economic expenses and improve system reliability.

Fig.2 'Multi-station integration' architecture of full DC bus
At present, 'multi-station integration' mainly includes data center operation mode, energy storage station operation mode and charging station operation mode suitable for new energy vehicles. The energy storage station is applied to the power generation side and distribution network side, which improves the utilization rate of various energy sources, and new energy can be better accepted. It also effectively solves the intermittent and uncertain problems of wind energy, photovoltaic power generation, etc. when the energy storage station is configured on the power generation side or distribution network side. Data centers are for large Internet enterprises, such as Apple, Google, Facebook, Baidu, Ali and Tencent. At present, data centers built and operated by third-party enterprises can provide cloud data storage, cloud computing, data analysis and processing services to government, enterprises and individual users, and obtain corresponding benefits by providing rental services of cabinets and cloud services to various users.

4. Conclusion
This paper introduces the data center power supply mode, energy storage configuration and the development status of renewable energy application, with emphasis on the advantages of DC power supply mode, and the future prospect of gradually replacing AC UPS power supply as the main power supply mode. Thanks to the vigorous development of the Internet industry in recent years, the scale of the data center is expanding rapidly, which is followed by huge energy consumption and expensive expenses. The power supply mode based on renewable energy and advanced energy storage technology can alleviate this series of problems to a great extent, and will also become an important research direction of the data center in the future.

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