Current Situation and Application Prospect of Energy Storage Technology

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Abstract. The application of energy storage technology can improve the operational stability, safety and economy of the power grid, promote large-scale access to renewable energy, and increase the proportion of clean energy power generation. This paper reviews the various forms of energy storage technology, compares the characteristics of various energy storage technologies and their applications, analyzes the application status of energy storage technology, and prospects the application prospects of various energy storage technologies.

1. Introduction

China's energy is large, but the energy structure is complex. The northwestern region has abundant energy stocks, but its demand is low. The southeast is densely populated, energy demand is large, and energy and demand are geographically dislocated. At the same time, with the substantial increase in the proportion of renewable energy utilization, the intermittent and random nature of wind power and solar power generation also pose challenges to the stable operation of the power grid. The energy storage industry is the key and driving force for the transformation of the energy structure. Accelerating the development of the energy storage industry is of great significance to ensuring the stable operation of the power grid, promoting large-scale access to new energy sources, and building a healthy energy output and consumption system.

2. Introduction to major energy storage technologies

According to the storage form of energy, energy storage technology can be divided into physical energy storage, electromagnetic energy storage and electrochemical energy storage physics. Physical energy storage mainly includes pumped storage, compressed air energy storage, flywheel energy storage, etc.; electromagnetic energy storage mainly includes supercapacitor energy storage, superconducting energy storage, etc.; electrochemical energy storage mainly includes lead acid battery, lithium ion battery, lead Carbon battery, sodium sulfur battery, flow battery, etc. The characteristics and application scenarios of various energy storage technologies are shown in Table 1.
Table 1. Characteristics and applications of energy storage technology.

| kind                  | Typical rated power | Characteristics                                                                 |
|-----------------------|---------------------|---------------------------------------------------------------------------------|
| Physical energy storage |                     |                                                                                 |
| Pumped storage        | $10^4 \sim 2 \times 10^6$ | Suitable for large-scale energy storage, mature technology, slow response, limited by geographical conditions |
| Compressed air energy storage | $10^4 \sim 3 \times 10^5$ | Suitable for large-scale energy storage, slow response, limited by geographical conditions |
| Flywheel energy storage | $5 \sim 10^4$ | Long life, high specific power, no pollution, high cost |
| Electromagnetic energy storage |             |                                                                                 |
| Superconducting magnetic energy storage | $10 \sim 5 \times 10^4$ | Fast response, high specific power, low temperature conditions, high cost |
| Supercapacitor energy storage | $10 \sim 1000$ | Fast response, high specific power, high cost and low specific energy |
| Sodium-sulfur battery | $100 \sim 10^5$ | Higher specific energy and specific power, high temperature conditions, operational safety issues need to be improved |
| Electrochemical energy storage |             |                                                                                 |
| Lead-acid batteries | $1 \sim 10^4$ | Mature technology, low cost, short life and environmental problems |
| Flow battery          | $1 \sim 10^4$ | Long life, deep discharge, easy combination, good environmental performance, low energy storage density |
| Lithium Ion Battery   | $1 \sim 10^4$ | High specific energy, good cycle characteristics, group life needs to be improved, safety issues need to be improved |

Table 2. Characteristics and applications of energy storage technology.

| kind                  | Discharge time at rated power | Application                                                                 |
|-----------------------|------------------------------|-----------------------------------------------------------------------------|
| Physical energy storage |                              |                                                                             |
| Pumped storage        | $4 \sim 10$ h               | Peak shaving, daily load regulation, frequency control, system backup      |
| Compressed air energy storage | $1 \sim 20$ h               | Peak shaving, frequency modulation, system backup, smoothing renewable energy power fluctuations |
| Flywheel energy storage | $1 \sim 1800$ s             | Peak shaving, frequency control, uninterruptible power supply, power quality control |
| Electromagnetic energy storage |                      |                                                                             |
| Superconducting magnetic energy storage | $2 \sim 300$ s | Transmission and distribution stability, suppression of oscillation |
| Supercapacitor energy storage | $1 \sim 30$ s              | Power quality control                                                     |
| Sodium-sulfur battery | $H$                          | Power quality control, backup power, smooth renewable energy power fluctuations |
| Electrochemical energy storage |                      |                                                                             |
| Lead-acid batteries | $\text{min} \sim \text{h}$ | Backup power, black start                                                   |
| Flow battery          | $1 \sim 20$ h               | Backup power, energy management, smoothing renewable energy power fluctuations |
| Lithium Ion Battery   | $\text{min} \sim \text{h}$ | Power quality control, backup power, smooth renewable energy power fluctuations |
3. Application Status and Development Prospect of Energy Storage Technology

3.1. Current status of energy storage technology application
Among many energy storage technologies, pumped storage is still the most mature and widely used large-scale energy storage technology, and its application has been more than 100 years. By the end of 2018, China's pumped storage capacity accounts for about 96% of the installed capacity of stored energy, and the release time of stored energy can range from a few hours to several days, with a comprehensive efficiency of about 75% [3]. The main application problem of pumped storage is that its construction has higher requirements on geographical conditions, longer construction period and larger single capacity. It is more and more difficult to find for application construction sites close to the load center. These factors will limit and slow down. The further development of pumped storage in the future energy storage industry.

In recent years, with the continuous maturity of electrochemical energy storage technology and the rapid decline of cost, China's electrochemical energy storage has grown rapidly. The total installed capacity has increased from 105MW in 2015 to 1.034GW in 2018, an annual increase of 114% to 2018. At the end of the year, the total installed capacity of energy storage was about 3.3%. Among them, lithium-ion batteries accounted for about 72%, lead-acid batteries accounted for about 25%, and flow batteries accounted for about 2% [3].

3.2. Prospects for energy storage technology development
At present, electrochemical energy storage technologies such as lithium-ion batteries, all-vanadium flow batteries and lead-carbon batteries with high technology maturity are basically operating in the market, and iterative development in the growing energy landscape will be expected in the next 20 years. Occupy most of the electrochemical energy storage market.

1) Lithium-ion battery [4-8]
Lithium-ion batteries have the advantages of high energy storage density, high energy efficiency, wide operating temperature range, small self-discharge, long cycle life, etc., and have become the main form of application and demonstration of large-scale energy storage systems. In recent years, lithium iron phosphate and ternary lithium batteries have become the mainstream of lithium ion research and application. The ternary lithium battery has the characteristics of high voltage, high energy density, low cost, good low temperature performance, etc. It has unique advantages in the field of high energy density power battery. The ternary lithium battery has high temperature due to unstable structure at high temperature. Poor safety, safety issues have become a key constraint limiting its widespread use in energy storage. Lithium iron phosphate battery exhibits high cycle life, high safety and relatively high specific energy density, making it still the current power car and The most powerful force in the field of electrochemical energy storage.

2) Lead carbon battery [6, 9]
Lead carbon batteries have the advantages of lower cost, better safety and higher renewable recovery rate, and are one of the currently relatively economically viable power storage technologies. At present, although the cycle life of lead-carbon batteries is significantly higher than that of lead-acid batteries, there is still a significant deficiency compared to lithium-ion batteries. Lead carbon battery development direction is to further improve energy density, power density and cycle performance, develop cheap, high-performance carbon materials, further reduce battery costs, and control the risk of hydrogen evolution caused by the introduction of carbon materials.

3) Flow battery [6, 10, 11]
The flow battery is an electrochemical battery in which both the positive and negative active materials are liquid. For many years, scholars from various countries have proposed a variety of different flow battery systems, by changing two oxidation-reduction reactors such as an all-vanadium system, Bismuth vanadium system, full chromium system, bromine system, whole uranium system, iron chromium system, etc. Among them, the most mature technology and the most widely used is the all-vanadium flow battery. The high safety of the flow battery, the consistency of the power, the long life
and the flexible expansion of the power capacity are highly compatible with the needs of the power storage market.

Although the flow battery is a good energy storage battery with commercial prospects, the shortcomings are also very prominent: the key technologies such as diaphragms are subject to foreign monopoly, resulting in high cost and low energy conversion efficiency, only 70%-80%; The energy density and power density are low; the floor space is large and the system cost is high. With the continuous breakthrough of new technologies and new systems and the stability of raw material prices, its ultra-high integration scale advantage will make it occupy a place in the energy storage market.

4. Summary
In general, in the case of limited development of traditional pumped storage, electrochemical energy storage will become the main driving force for the future development of the energy storage industry. Compared with traditional lead-acid batteries, lead-carbon batteries have significantly improved the charge-discharge rate, cycle life and production cost, and the cost-effective advantages are significant. The main limiting factors are the environmental pollution problems caused by the recycling process of electrode materials; The cycle performance is good, the capacity and power can be adjusted independently, which is very suitable for large-scale energy storage application scenarios. However, some key materials rely on imports to cause high cost. With the continuous breakthrough of new technologies and new systems and the reduction of raw material prices, The high integration scale advantage will make it occupy a place in the energy storage market; lithium iron phosphate battery has good safety, long cycle life, high flexibility, and has both power and energy advantages. In addition, through decommissioning lithium iron phosphate battery The energy storage application can further reduce the cost of energy storage construction while digesting part of the cost of electric vehicles. It can also alleviate the resource waste and environmental pollution caused by the decommissioning of a large number of power batteries. The economic and social benefits are significant, and the lithium iron phosphate battery will still be present and even The main force in the field of power storage for a long time.

References
[1] Lin Haixue General Situation and Prospect of Modern Energy Storage Technology [J]. Journal of Power Supply 2015, 13(5): 34-47.
[2] Liu Yingjun, Liu Chang and other energy storage development status and trend analysis [J]. Chinese and foreign energy 2017, 22 (4): 80-88.
[3] Zhang Donghui, Xu Wenhui et al. Application scenarios and development key issues of energy storage technology [J]. Southern Energy Construction, 2019, 6 (3): 1-5.
[4] Li Xianfeng, Zhang Hongzhang Electrochemical Energy Storage Technology in Energy Revolution [J]. Low Carbon Multi-Energy Fusion Development 2019, 443-449.
[5] Ma Hua, From Chang Jie et al. Research progress in lithium ion power batteries for energy storage [J]. Chemical Industry and Engineering 2014, 31(3): 26-33.
[6] Jiang Kai Power Storage Technology Progress and Challenges [J]. Power Demand Side Management 2017, 19(4): 1-5.
[7] Zhou Fang, Liu Si et al. Application and development trend of lithium battery technology in energy storage [J]. Power Technology 2019, 43(2): 348-350.
[8] Hua Zhigang Key Energy Storage Technology and Commercial Operation Mode [M]. China Electric Power Press 2019.1.
[9] Jiang Kai, Li Hao, et al. Introduction of several types of energy storage batteries for power grids [J]. Automation of Electric Power Systems 2013, 37(1): 47-53.
[10] Xie Congxin, Zheng Qiong et al. Recent Developments in Flow Battery Technology [J]. Energy Storage Science and Technology 2017, 6(5): 1050-1057.
[11] Yang Yang, Liu Na et al. Research progress of all vanadium redox flow battery electrolytes [J]. Power Technology 2019, 43(4): 706-709.