Typical Application of Energy Storage in Power System

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Abstract. The rapid improvement of renewable energy has brought great pressure to the power grid. To solve the problem, energy storage has been valued as an important flexible resource. Different types of energy storage have significant differences in technical and economic characteristics, and have different applications in power system. Now high capacity energy storage is playing a crucial part in ensuring the power system security and reliability, strengthening the peak-valley load regulation ability of regional power system, improving the capacity of power transmission and transformation, and improving the quality of electric energy. The performance and characteristics of different energy storage forms were discussed and the use of energy storage was analyzed in this paper. It could be concluded that energy storage will become more essential in the power system.

1. Introduction
As the global energy situation is tense and global warming has brought serious harm to economic development and human health, countries around the world are seeking new energy alternative strategies. Among the many renewable energy methods, wind power generation and photovoltaic power generation are considered as the two most promising technologies. However, it is difficult for the independent operation system of wind and light to output continuous and stable power supply. Compared with the stable power supply of thermal power, it will reduce the power grid security and stability. Power storage systems effectively improves the influence of renewable energy and open up a new road to resolve the current energy crisis and environmental pollution [1-5].

2. Classification of Energy Storage

2.1. Classification of Energy Storage
On the basis of types of energy, energy storage system can be classified in electrochemical, electromagnetic and mechanical energy storage. Electrochemical energy storage contains lead-acid battery storage, lithium iron phosphate battery storage, sodium sulfur battery and liquid flow battery storage. Electromagnetic energy storage contains superconducting magnetic energy storage and supercapacitors [6]. Mechanical energy storage contains pumped storage, flywheel energy storage and compressed air energy storage.

The type, capacity and structure have great influence on the performance, technology and economy of the whole energy storage system [7].
2.2. Classification of Energy Storage Battery
In comparison with other types, electrochemical energy storage can be installed in all links of power system and less hard to decide the system location. The installation of energy storage devices with large-scale battery in distribution network can effectively achieve peak-valley clipping and improve load characteristics. Because of the characteristics of application environment, only energy-based energy storage systems are generally taken into account. Currently, the electrochemical energy storage devices with high frequency used and suitable for peak-load shaving in distribution network mainly include lead-acid battery, lithium-ion battery, all-vanadium liquid-flow battery and sodium-sulfur battery.

2.2.1. Lead-Acid Battery. Lead-acid batteries have a long development time and relatively early service time. In comparison with other battery types, lead-acid batteries are more mature. Lead-acid batteries have merits of lower cost, higher rate of recovery, lower self-discharge, higher specific capacitance and higher current performances. But the lead is a kind of heavy metal, which is harmful to the environment and people’s health. Furthermore, lead-acid batteries are of relatively shorter lifespan, more frequent maintenance and lower power density, so they are unsuited for occasions where both power and capacity are required. These disadvantages restrict the use of lead-acid batteries, so lead-acid batteries alone can only play a limited role in energy storage.

2.2.2. Lithium Ion Battery. Lithium ion batteries consist of liquid lithium ion batteries and polymer lithium ion batteries. In recent years, the electrode and electrolyte of lithium battery are gradually innovated and the production technology of auxiliary equipment is further mature. The production cost of lithium ion battery has a significant reduction. The cost reduction will be benefit the wide promotion and application. Lithium ion batteries have merits of higher energy storage density, smaller in size, no pollution, lower self-discharge rate, faster charging and discharging speed, better power characteristics. So lithium ion batteries have become ideal for energy storage stations. But lithium ion batteries are of low battery capacity, intolerance of overcharging and over discharging, and very expensive price.

2.2.3. Flow Battery. The flow battery is a innovative type of electrochemical energy storage technology. It is a kind of green environmental protection energy storage battery. The capacity of all-vanadium flow batteries is decided by the concentration of active substances and the capacity of liquid tank, rather than the limitation of the battery itself, which is fit for high-capacity energy storage system. The merits of all-vanadium flow batteries are as below: the cycle life can scratch more than 16,000 times and the life is long; All-vanadium flow batteries support deep charge and deep discharge, and frequent charge and discharge would not shorten the battery life; The capacity can be under real-time supervision, which is convenient for practical control. The main disadvantages are large battery volume, equipment corrosion, low battery energy efficiency, more stringent requirements on the environmental temperature.

2.2.4. Sodium-Sulfur Battery. Sodium-sulfur batteries work under the high temperature of 300 ℃. The advantages of Sodium-sulfur batteries include higher specific energy and higher energy conversion efficiency. And the self-discharge factor can be ignored in operation of charging and discharging. Sodium sulfur batteries have superior performance in deep discharge, and the application of sodium sulfur batteries is relatively mature in power grid. However, the disadvantages are still significant. Sodium sulfur batteries must operate in temperature above 300℃, which is strict in the battery charging and discharging process. The active material of sodium sulfur battery electrode is in the melting state, and the electrolyte and stability requirements are high. So there are a few security threats
which is bad for the long and stable operation of the sodium sulfur battery energy storage power station.

3. Typical Application of Energy Storage

3.1. Typical Application in Power System

Energy storage devices are widely used in the power system and have a great influence on the power system. The specific use is shown in Table 1.

| Type                     | Application                        | Proportion |
|--------------------------|------------------------------------|------------|
| Ancillary service        | Frequency modulation               |            |
| New energy connection    | Grid Smoothing power               |            |
| Power distribution       | Grid-side storage                  |            |
| Distributed generation   | In Islands                         |            |
| Others                   | Mobile energy                      |            |

Table 1. Typical application of energy storage in power system.

3.2. Application in Connecting the New Energy Systems

3.2.1. Smoothing Output. Wind power generation and photovoltaic power generation connecting to the power grid will cause frequency fluctuations of the power grid, thus increasing the burden of auxiliary services such as frequency modulation, voltage regulation and operation dispatching of the power grid, resulting in an increase in the operation cost of the power system. When the fluctuation is beyond the peak load range of the power system, it will further lead to the frequency limit and seriously threaten the safe operation of the power system [8]. The energy storage system can smooth the fluctuation of the output power of renewable energy and connect the renewable energy to the power grid to make the operation of the power grid more stable. It is generally divided into short-term power fluctuation and long-term power fluctuation. When this system is used to smooth the short-term power fluctuations of renewable energy, the smoothing time scale is generally from seconds to tens of minutes. When the energy storage system is used to smooth the long-term power fluctuations of renewable energy, the energy storage system is mainly used to compensate for the mismatch between the power output of renewable energy and the load demand, whose time scale ranges from tens of minutes to hours.

3.2.2. Power Generation Plan. In accordance to the demand of the power market or the load forecast, the power grid dispatching agencies at all levels of the power system arrange the power generation plan for the power generation equipment within the scope of management. Taking the daily power generation plan as one instance, the hourly load is usually represented by the hourly load. There are many ways to plan the generation target curve, such as considering the rate of load change. The generation plan of the power system at a given time under a given load level can be worked out under known conditions such as power system load, unit combination, tie line plan, exchange plan, standby plan, unit economic characteristics and various operating limitations, so as to minimize the generation
cost of the whole system. If the target curve of planned power generation is made according to the load condition or the situation of renewable energy generation, but on account of the uncontrollable and intermittent nature of renewable energy, the system is required to complete the target curve. The deviation between the planned generation target curve and the renewable energy output needs to be compensated by the energy storage system [9].

3.2.3. Peak Load Shaving. Peak load shaving generally refers to the arrangement of partial load in the peak load period into the trough load period through the dispatching of the generation side or the electricity side so as to reduce the peak load of the system, increase the trough load of the system and increase the load rate. Because power plants produce electricity 24/7, if the electricity is not used, the energy used to generate electricity is wasted. A power plant's generating capacity is usually fixed, but the peak is usually during the day, resulting in insufficient power during the day and low power at night. In view of this phenomenon, the power system moves part of the peak load to the night trough, thus making use of the surplus power at night and achieving the purpose of energy saving. The release of the system can be used to complete peak cutting and valley filling [10].

3.2.4. Hybrid Application. Hybrid application refers to the energy storage system playing the above different roles simultaneously. It is defined as a smoothing peak clipping scenario. In other words, this system is used to smooth the net load that fluctuates sharply while the peak clipping and valley filling is processed.

4. Conclusion
Energy storage technology has positive effects on promoting global energy conservation, emission reduction and energy structure optimization. With the increase of the proportion of renewable energy, the market prospect of large-scale energy storage, the development of smart grid, government support and the pursuit of capital are gradually emerging. It has been applied in the entire process of the power system’s development, transmission, supply, distribution and use, so as to improve the utilization rate of new energy generation and access capacity, achieving the goal of green energy conservation, alleviating the peak load power demand and improving operation efficiency of the existing power grid and its equipment. Besides, it can also improve the power quality and efficiency, ensure the reliable supply of high quality and safety, satisfy efficient power consumption of the power grid, and promote the optimization of the structure form, planning and design, dispatching management, operation control and use mode of the power grid.

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