An Analysis of the Application of Energy Storage Technology in Power Systems

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Abstract. With the rapid development of China's economy, the coverage area of China's power grid is expanding, and users have higher requirements for the quality and reliability of electrical energy. And the development of energy storage technology has improved the stability of power system operation, voltage and frequency regulation, load compensation, and also injected new development ideas into the planning and design of power systems, manufacturing control, etc. Energy storage technology occupies a very important position in the power system, the needs of its power system so as to enhance the availability of renewable energy and ensure that the power system can operate safely and stably. This paper provides further analysis and discussion on the application of energy storage technology in power systems.

1. Introduction
Energy storage technology mainly refers to the storage of electrical energy, where different amounts of energy are stored through specific devices or physical media, and the stored energy can be used for emergency energy. The addition of energy storage technology to the power system can effectively achieve energy storage when the grid load is low and energy output when the grid load is high, which can eliminate the valley-peak difference and smooth the load. This not only allows for efficient operation of electrical equipment, but also reduces the cost of power supply and perfectly promotes the use of renewable energy. Energy storage technology in the application of power systems is mainly divided into two categories: physical storage and chemical storage, of which physical storage includes pumped water storage, compressed air storage, flywheel storage, supercapacitor and superconducting electromagnetic storage; chemical storage includes lead-acid batteries, liquid flow batteries, nano-system batteries, lithium-ion batteries. Various types of energy storage technologies have different energy and power densities in the application of power systems, and based on the needs of our power system, the application of power storage technologies in power systems is worth research and development.

2. Common energy storage technologies
2.1. Pumped energy storage
Pumped energy storage is the largest scale and most widely used electric power storage system among the energy storage technologies available in China. Pumped energy storage is equipped with upstream and downstream reservoirs to pump water from downstream to upstream books for conservation during low power loads [1]. And pumped storage during peak hours of electrical load can then generate
electricity from the water stored upstream. The design and planning of pumped energy storage has formed a norm, and the technology level is relatively perfect and mature, and the unit has developed from the earliest four-engine unit to a two-cycle unit composed of hydroelectric motors, which has greatly reduced the floor space and input costs. Pumped energy storage equipment has a long service life, low energy self-dissipation rate, and high overall efficiency. Depending on the volume of the reservoir, the release of energy storage energy can be as long as several days, with a combined efficiency of 75%-90%. Pumped energy storage is also critical in power system applications such as peak and valley regulation, frequency and phase regulation, accident handling, and providing backup capacity for the system. However, pumped energy storage also has certain drawbacks, such as low energy density, geographical conditions are restricted, long return on investment cycle, so the relevant departments and the power industry should study the corresponding improvement measures as soon as possible, and accelerate the research of seawater pumped energy storage technology according to national conditions.

2.2. Compressed air energy storage
Compressed air energy storage is the use of electricity grid electricity low valley, the remaining electricity compressed air pressure, the air in the air compressor for compression and storage in the pressure of 7.5Mpa high pressure sealed equipment, the electrical energy effectively into air energy, in the grid electricity peak, re-release the air in the air compressor to drive the gas turbine power generation. In the process of turbine power generation, 3/2 of the fuel is used for air compression, and the fuel consumption is reduced to 1/3, consuming 40% less gas than conventional turbines, which greatly reduces the input itself and also reduces emissions [2]. In recent years, the development of compressed air energy storage is also very active, traditional natural gas and underground caves of air compression energy storage power plant technology is also relatively mature, reached in a single operating scale of 100MW; Tsinghua University and other units jointly developed 500KW non-supplementary combustion compression energy storage system, also in Datong, Shanxi and other places to implement 100 MW-level projects. Compressed air energy storage is mostly used for peak and valley power recovery and regulation, load balancing, distributed energy storage and power generation system backup. However, traditional compressed air energy storage will still be limited by geographical conditions, so we need to accelerate the research on several other compressed air energy storage technologies, such as supercritical, advanced adiabatic isothermal compressed air energy storage technology and liquid air energy storage technology. Focus on breaking the technical difficulties and increasing the density of compressed air energy storage.

2.3. Flywheel energy storage
The flywheel energy storage system consists of a high-speed flywheel, an electric motor, a bearing support system, a power converter and other equipment. In the low power load, the industrial frequency grid provides electricity to drive the flywheel to rotate at high speed and store energy in the form of kinetic energy; while in the peak power load, the flywheel rotating at high speed drives the generator to generate electricity, and the energy generated by the rotational speed will continue to increase, thus driving the system operation and releasing energy process. Flywheel energy storage is suitable for power grid frequency regulation, power grid security and stability control, power quality management, etc. It is also commonly used in uninterruptible power supply work, the energy density of flywheel energy storage is more than 20Wh/Kg, the efficiency is above 90%, the service life is long, in recent years, China has also increased the in-depth research on flywheel energy storage, in addition to the application of electromagnetic and superconducting magnetic levitation bearing technology, also promote the development of flywheel energy storage. In general, the theoretical and applied research of flywheel energy storage technology in China has a large gap with the international level, especially the application of power system for flywheel energy storage technology. As China's flywheel energy storage system started late, which puts forward higher requirements for the research work of flywheel energy storage technology, some developers of flywheel energy storage technology have increased the development
progress, for the future flywheel energy storage technology can be coordinated with large generating units to run the control technology.

2.4. Ultracapacitor Energy Storage Technology
Supercapacitors are developed based on the electrochemical double layer theory and are suitable for applications where large pulses of power are required to be supplied for short periods of time, where the charge attracts anisotropic ions from the surrounding electrolyte, adsorbs to the electrode surface and increases by a factor of ten thousand, resulting in a large electrical capacity\(^3\). Supercapacitor energy storage can reach 21MJ/5.7Wh capacity with a maximum power of 1MW, but due to the high price, supercapacitor energy storage is mostly used in power systems for short periods of time and in places with high power quality power. Demonstration projects of supercapacitors have also emerged in China, and some domestic universities are working on supercapacitor energy storage technology.

2.5. Superconducting energy storage technology
Superconducting energy storage system is the use of superconductors formed by the coil to store energy, power delivery without conversion into other energy situations, can be in with the power system electrical capacity energy conversion as well as power compensation. Superconducting energy storage technology has the advantages of fast response time, high capacity power and high conversion efficiency. The gap between domestic and foreign research and development of superconducting magnetic energy storage is not obvious, only the United States, Japan and Europe have been the initial application of 100MJ superconducting magnetic energy storage system has been put into test operation, China's Chinese Academy of Sciences Institute of Electrical Engineering, Huazhong University of Science and Technology Chinese Academy of Electrical Sciences are developing prototype superconducting magnetic energy storage system with independent intellectual property rights.

2.6. Lead-acid battery energy storage technology
Lead-acid battery energy storage system has been acting as a backup power source in thermal power plants, wind power plants, photovoltaic power plants, substations and other power systems, maintaining the role of safe and stable operation of the power system, lead-acid batteries have been widely used in the field of energy storage. Lead-acid batteries have a high degree of technological maturity and the price of raw materials is also relatively cheap, with good float and even charging performance, thus having an extremely important role.

2.7. Liquid Flow Battery Energy Storage Technology
In recent years, China, the United States, Japan and European countries have laid out the research and application trials of liquid flow battery technology, and wind power and photovoltaic power generation with liquid flow battery energy storage system for power plant peaking. Liquid battery energy storage technology needs to be used in power systems on a large scale, with its fast response and high safety performance, while the electrolyte can be recycled for secondary use.

2.8. Sodium-sulfur battery energy storage technology
More than 100 sets of sodium-sulfur battery energy storage technology have been successfully applied in power systems, and the total capacity has exceeded 100MW. Sodium-sulfur battery applications cover peak shaving, stable renewable energy output, high charge and discharge efficiency, and have achieved more than 4,500 charge and discharge cycles. However, at present, China's sodium-sulfur battery energy storage technology, because of the electrode material and ceramic tube technology has a certain gap, so there is only in Shanghai Power sodium-sulfur battery energy storage power plant demonstration projects.
3. Issues to consider when applying energy storage technology to power systems

3.1. Power generation side

From the perspective of the power generation side, the demand side of energy storage technology is the power plant, and different power plants have different impacts on the grid. The demand for energy storage technology on the power generation side generally includes energy time shifting, capacity units, load tracking, system frequency regulation, standby capacity, and renewable energy grid connection.

Energy time shift: through energy storage technology to achieve power plants in the low load of electricity consumption when the battery charging, and in the peak of electricity consumption will be stored power release; capacity unit: because the load of electricity consumption in different times with differences, thermal power plants will need to undertake the work of peak regulation, so to set aside a certain amount of generation capacity as peak load energy, the use of energy storage technology will be in the low load of electricity consumption charging, in the peak of electricity consumption discharge to reduce the load spike; load tracking: slow change in the continuous change unit load can be balanced in real time to the scheduling instructions, but also according to the actual situation of the unit to adjust; system frequency regulation: system frequency regulation is a power-type application, in the use of chemical energy storage technology can be charged and discharged multiplier, the battery can be converted between charge and discharge state; standby capacity: in addition to meet the needs of the specified load, to the occurrence of unexpected situations to protect the power quality and the safe and stable operation of the unit with power storage; renewable energy to the grid: wind power and photovoltaic power output is characterized by randomness, power quality is unstable, renewable energy to power-type applications.

3.2. Transmission and distribution side

Mitigating transmission and distribution blockages: line blockage is when the load exceeds the capacity of the line, and energy storage systems are placed upstream of the line to store the undeliverable power in storage devices when the line is blocked, and generate power to the line when the line load is low. Deferring the expansion of transmission and distribution equipment: in most of the time can meet the load requirements, in a certain peak time when its own capacity is lower than the load, you can use energy storage technology through a smaller installed capacity to effectively mention the transmission and distribution capacity of the grid.

Reactive support: regulates transmission voltage by injecting or absorbing reactive power on transmission and distribution lines.

3.3. Improving power quality

Due to the variable nature of the operating load of the power system and the non-linearity of the equipment load, the power obtained by the user will have voltage, current and frequency deviations\(^4\), when the quality of the power is poor. System frequency regulation and reactive power support can enhance the way of poor power quality. Improving power quality is a typical power-based application, and the specific discharge market and operating frequency will be adjusted according to the actual application market.

3.4. Reliability of power supply

Energy storage technology applied to the power system, to improve the reliability of power supply, specifically in the event of a power outage or other power accidents, energy storage systems can supply the stored energy to the end user, in the event that the fault is not completely repaired, to effectively ensure the reliability of power supply, and this requires energy storage technology must have high quality, high reliability requirements, to cut the actual power supply and production.
4. The direction of energy storage technology in power systems
At present, China has carried out research on SMES, flywheel energy storage and supercapacitor and superconducting electromagnetic energy storage and other key technologies, but has not been put into operation in the power system, for the continuous expansion of China's power market, according to the national development strategy, the sustainable development of urban power grid comprehensive consideration, to "energy conversion key technology research," "energy storage technology key research" as the framework, strict deployment, to power storage technology as the premise of the research as the basis, to advanced energy storage system grid key technology as the main direction, to independent research and development and innovation of energy storage technology in the power system application of the core technology, and in the actual power system to promote the implementation. To develop sodium-sulfur battery energy storage technology, focus on SMES research for liquid nitrogen temperature zone operation, and accelerate the construction of GW-level pumped energy storage power plants with renewable energy sources in mind.

concluding remarks
In summary, power storage technology is shifting towards conversion efficiency, energy densification, and application cost reduction. Energy storage technology has a significant role in the power system through testing and practical use in the power system, playing an important role in peak and valley regulation, frequency and phase regulation, accident handling, frequency regulation, voltage compensation, power quality, etc., ensuring the safe and stable operation of the power system. According to China's energy distribution plan, the national power grid has formed a pattern of "west-east power supply, north-south mutual supply and national networking", which has solved regional power supply conflicts, improved transmission and transformation capacity, improved power quality of customers and enhanced the reliability of power supply. For this reason it is important to accelerate the application of energy storage technology in the power system in order to achieve the economic value of the grid system in maximizing.

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