The Application analysis of electrochemical energy storage technology in new energy power generation side

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Abstract. With the continuous increase of the installed capacity of renewable energy power generation in China, and the formulation of policies about allocating certain scale energy storage system for new energy power generation. The development of the electrochemical energy storage exhibits an explosive growth trend. In this paper. The current situation and characteristics of electrochemical energy storage technology are described from three aspects: The electrochemical energy storage technology, Integration technology of the energy storage system and the operation control strategy of energy storage system. Based on the typical demonstration projects of new energy equipping energy storage system. That have been implemented, the application direction. Implementation function and technical characteristics of energy storage in the field of new energy power generation side are analyzed. Furthermore. The main application functions and technology research trend of energy storage in new energy generation side are proposed. Finally, the prospect and development trend of energy storage technology in the new energy generation side in the future are prospected, four directions are given.

Key words: electrochemical energy storage, new energy, wind power generation, photovoltaic power generation, power generation side, ancillary services.

1. Introduction
With the continuous strengthening of national environmental protection, the installed scale of renewable energy power generation in China has expanded rapidly. According to the statistics from the national energy administration, by the end of 2019, the country's total installed wind power capacity was 210 million kW, of which 204 million kW was onshore wind power and 5.93 million kW was offshore wind power, accounting for 10.4% of the total installed power capacity. Installed capacity of photovoltaic power generation was added nationwide The total installed capacity was 30.11 million kW, of which 17.91 million kW was newly installed in centralized photovoltaic and 12.2 million kW was newly installed in distributed photovoltaic. The cumulative installed capacity of photovoltaic power generation reached 204.3 million kW, up 17.3% year on year. The proportion of installed capacity of renewable energy power generation is gradually increasing, but the new energy power generation is affected by the changes of natural resources such as wind and light, and it is difficult to predict, control and dispatch the power.

The quantitative and transient stability are affected. At the same time, China's energy structure is undergoing a gradual transformation, and it is necessary to cope with the challenges brought by
continuously increasing wind power generation and photovoltaic power generation to the stable operation of the power system and power grid.

The rapid development of energy storage technology provides the feasibility to solve the above problems. Energy storage technology can play a corresponding role in the power system’s development, transmission, distribution and use, increase the flexibility of the power transmission link, and enable the power to have the ability of time and space transfer, which is of great significance for ensuring the security of the power grid, improving the power quality, increasing the proportion of renewable energy, and improving the energy utilization efficiency. This paper mainly analyzes the application of electrochemical energy storage in new energy generation.

2. Electrochemical energy storage technology

Electrochemical energy storage is one of the most widely used, fastest developing and best based energy storage technologies except pumped storage. This technology is not a new technology, but its combination with new energy is an urgent field to be developed.

2.1. Electrochemical energy storage battery technology

There are many kinds of electrochemical energy storage batteries, and the appropriate technology should be selected based on the specific application field and functional requirements, as well as the comprehensive comparison of the advantages and disadvantages of each battery technology. To choose the main technical features include: energy density, power density, response time (ms, s, minute), energy storage efficiency (charge and discharge efficiency), equipment life (year) or the charge and discharge times, cycle life, technical maturity, self-discharge, and economic factors (cost of investment, operation and maintenance costs), safety and environment aspects and so on.

From the current application of electrochemical energy storage technology in China, lithium ion batteries and lead-acid batteries account for the absolute proportion, while the rest of the liquid flow batteries and sodium-sulfur batteries are used in a small part. From the analysis of application field, lithium ion battery is mainly used in renewable energy grid-connected energy storage and auxiliary service field. Since 2018, a large number of electrochemical energy storage projects on the power grid and power generation sides have been built and put into operation. There are many kinds of lithium ion batteries, and the technical parameters of mainstream lithium ion batteries are shown in table 1.

| Project specific energy/(W·h·kg⁻¹) | lithium iron phosphate | lithium manganese | lithium cobalt oxides | Ternary lithium (lithium nickel cobalt manganate) | lithium titanate |
|----------------------------------|-----------------------|-------------------|-----------------------|-------------------------------------------------|------------------|
| Charging(multiplier)             | 130–160 1C, maximum 4C | 130–180 0.7–1C, maximum 3C | 180–260 0.7–1C, more than 1C will shorten the life | 180–240 0.7–1C, more than 1C will shorten the life | 50–80 Typical 1C, maximum 5C |
| Discharge (multiplier)           | 1C, can achieve 2.5C   | 1C                | 1C                    | 1C, can achieve 2.5C                             | Can be up to 10 C |
| Cycling/secondary                | 2 000–6 000           | 500–2 000         | 500–1 000             | 800–2 000                                       | >10 000          |
| Thermal control                  | 270 °C, Full, very safe. | 250 °C, High loads promote uncontrolled heat | 150 °C, It is easy to get out of control of heat | 210 °C, High loads promote uncontrolled heat | The safest The lithium battery |
| Environmental protection to adapt to the field | non-poisonous Large-scale storage | non-poisonous Large-scale storage | Cobalt toxic Traditional 3C products | Nickel and cobalt are toxic | non-poisonous Large-scale storage |

Table 1. The technical parameters of mainstream lithium ion battery
Lithium iron phosphate battery has good structure stability and thermal stability Characteristics, excellent high temperature cycle performance, after the improvement of the battery capacity up to 165 mAh/g, so it is widely used, but lithium iron phosphate production technology requirements are high, batch production consistency is poor;he high temperature capacity of lithium manganate battery is seriously attenuated, and the structure is unstable during charging and discharging, which affects its widespread use. Because of the poor safety performance of lithium cobalt oxide battery, it is limited to use occasions. Ternary materials have concentrated the advantages of composite materials, and their combined performance is better than that of a single compound. In the process of charging and discharging, ternary materials can maintain a stable layered structure with higher capacity. However, their energy density is relatively increased, which brings thermal runaway problem and safety hazard to the application. Lithium titanate battery has poor electrical conductivity and high price, which makes it impossible to realize large scale model application.

In addition to lithium ion battery, sodium sulfur battery, liquid flow battery also have a small number of applications in the power side. Sodium sulfur battery has higher energy (up to 760 W·h/kg in theory, 3~4 times as much as lead-acid battery) and higher power density (up to 100% charge and discharge efficiency), but it is necessary to prevent sodium in use. Severe exothermic problems caused by direct reaction with sulfur. Considering economy and safety, sodium-sulfur batteries are not suitable for large-scale electric energy storage. There are many kinds of liquid flow batteries, such as full vanadium oxidation reduction liquid flow battery, zinc-bromine liquid flow battery, zinc-oxygen (air) liquid flow battery, etc. The power rate depends on the area of the single battery, the number of layers and the number of series and parallel of the electric reactor. The capacity depends on the concentration of the electrolytic liquid product and the active material. It has the characteristic of power and capacity being independent from each other.

Others, such as lead-acid battery, have advantages in price, but have low energy density, poor power characteristics and short life. Lead-acid battery is introduced into carbon material by negative electrode material to form lead-carbon battery. Although the sexual energy of the original material is improved, its energy density is low, and its comprehensive performance cannot meet the energy storage application of large-scale new energy generation side.

2.2. Energy storage system integration technology

For specific applications, energy storage system integration technology and way is relatively important to determine the overall use efficiency and function. It mainly involves battery grouping technology, electrochemical energy storage converter system technology and the corresponding system topology. Meanwhile, the operation of energy storage battery requires the technical support of the battery management system.

1) Battery grouping leads to life problems. Due to the objective existence of battery inconsistencies, the capacity, internal resistance and charging and discharging characteristics of group batteries need to be consistent. After integration, the balancing strategy should be adopted to realize the performance uniformity as much as possible and the overall performance is good, which is conducive to the prolonging of battery life.

2) Temperature control. Temperature has obvious influence on battery capacity and even life and safety. The cooling mode, heat dissipation structure, heat insulation mode, air duct design and other related thermal management technologies are considered in the battery group.

3) Electrical safety. The battery system is a high energy body, through a reasonable series, parallel connection mode to achieve shunt partial pressure, prevent local electrical safety accidents.

4) Electrochemical energy storage converter is the hub connecting energy storage and ac power grid. According to the different scale level, its application scene is different. MW electrochemical energy storage is generally used in new energy generation side, so the research of energy storage converter with high power and large capacity is the current trend.

5) System topology is the specific application scenarios, based on technology to comprehensive application, including dc/ac charger, voltage, power/current distribution, optimal arrangement, etc., of
energy flow, information flow (control information, state information) reasonable system structure, high efficiency, safety and stability of power exchange.

6) the battery management system realizes efficient management of the battery system. It includes the accurate estimation of the remaining battery capacity (SOC), the management of healthy state and fault state, and the energy efficiency analysis based on data processing. Among them, the accurate calculation of the remaining battery capacity (SOC), the high-precision data acquisition and processing, and the state management methods are the research hotspots.

2.3. Operation control strategy of power generation side energy storage system
Energy management system is different energy and a variety of information management Fusion. Aiming at the grid-connection field of large-scale new energy generation side, considering the requirements of auxiliary service of energy source measurement, economy, system reliability and security and other objectives and constraints, it is the current research direction to study the joint operation control strategy of new energy source and electrochemical energy storage system based on different goals and trends. Such as new energy power generation output volatility as a condition about beam, joint considering power generation plan output deviation, combined the technology of renewable energy power prediction at the same time, based on the energy storage capacity is limited, on the basis of real-time electricity price factors such as build system optimal performance index operation mode, through effective coordination control strategy, the maximum tracking power output plans and achieving the optimal energy storage battery operation, beneficial to extending energy storage battery in service life, realizing the maximum energy storage equipment utilization. Based on the specific regional load, the joint control strategy of the scenic storage system maximizes the utilization of scenic resources and smoothes and stabilizes the power.

3. Application status of electrochemical energy storage in new energy generation
Due to the power generation characteristics of new energy can not be ignored on the safety and stability of the power grid production, the power grid companies have put forward strict requirements on the new energy grid interconnection index. In addition, the centralized reactive power compensation device installed to make up for the problems caused by MPPT mode of new energy brings challenges to the investment and operation of new energy, so it is necessary to explore a new combination mode of electrochemical energy storage and new energy generation.

In practical application, electrochemical energy storage is generally divided into power type and capacity type. Power-type applications require fast response capability, such as quick participation in FM/regulator auxiliary services and fast power suppression, which is not high for continuous time; Capacitance-type applications require a longer discharge interval, which requires the support of a larger capacitance in a certain period of time.

In recent years, China's new energy generation side configuration energy storage can be divided into two stages. The first stage is the demonstration project stage, and some project cases are shown in table 2.
Table 2. Some demonstration projects of energy storage at the new energy power generation side

| Project                                           | Energy storage size | Energy storage technology type | remark                                                                 |
|---------------------------------------------------|--------------------|-------------------------------|------------------------------------------------------------------------|
| National scenic storage and transportation project | 33 MW/95.5 MW·h    | Lithium battery 24MW / 66MW·h; Lead acid battery 2 MW/12 MW·h; Lithium titanate battery 1 MW/0.5 MW·h; Flow battery 2 MW/8 MW·h; super-capacitor | Low battery power, smooth output, tracking plan Peak load regulation, FREQUENCY/voltage regulation |
| China national energy group co., LTD              | 5 MW/10 MW·h       | V flow battery 0.5c           | 0.5C                                                                   |
| National energy group north town energy storage type wind farm | 8 MW/14 MW·h | Lithium iron phosphate 5 MW/10 MW·h; Vanadium flow battery 2 MW/4 MW·h; Supercapacitor 1 MW/33 kW·h | 0.5C (battery) 3C (capacitor)                                                                 |
| Huaneng qinghai golmud photovoltaic energy storage power station project | 15 MW/18 MW·h | iron phosphate | 1C smooth output, peak modulation, frequency modulation, solution to discard light |

From the point of view of the demonstration project: the discharge rate of the energy storage system is low. Follow up the plan and participate in peak adjustment. A few try to participate in frequency/voltage adjustment at high rate. The mainstream uses the lithium iron phosphate battery, tries the liquid flow battery application. From the analysis of battery power configuration, the demonstration energy storage project basically does not have the capability of frequency modulation. It can be seen that lithium ion battery or liquid flow battery is generally regarded as the main battery technology in this application field, and the current direction is the capacity function of non-adjustable frequency, among which lithium iron phosphate battery has a high market share. In addition, ultracapacitors have fast power response, which belongs to the power type, and have been tried in the field of fast FM service.

In the second stage, a quantitative energy storage project is configured for new energy projects. The eye. Released so far, some provinces have been clear about the scene with store to relevant policy documents, such as the requirements of new wind field in Qinghai province with 10% energy storage capacity, the Xinjiang Uygur autonomous region to encourage 10 MW / 10 MW photovoltaic configuration h. energy storage capacity, notify the new wind farm configuration of Hunan province 20% energy storage capacity, the Anhui province notification form a complete set of wind power energy storage capacity of 20%. At present, nearly 20 wind power energy storage projects have been reported in China. From the perspective of energy storage scale, the proportion of energy storage in the recent projects varies from 10%, 20% to 25%, and the energy storage duration is 1 to 2 hours. The energy storage time of the project only adopts all-vanadium liquid flow battery is 4 hours.

From the current configuration provinces in view of the new energy storage requirements and actual project implementation result, battery main body configuration 1 C rate, energy storage duration of 1 h, a few USES 0.5 C ratio, chose the phase of high safety, low cost pressures and capacity battery, mainly to achieve smooth output, tracking service functions such as planning, participate in peak shaving. Based on the current battery technology and cost investment, as well as the new energy storage combined FM/voltage regulation technology, the new energy storage combined FM needs to be further studied, and corresponding incentive policies are also needed.
For example, wind power generation and photovoltaic power generation are larger than the examples, leading to high peak pressure for other power generation, such as thermal power, and a higher proportion of energy storage configuration. At the same time, it is necessary to balance the cost and promote the healthy development of new energy.

4. Application analysis of electrochemical energy storage in new energy generation

Renewable energy power generation is characterized by randomness, intermittency and volatility. In order to enhance the schedulability of renewable energy power generation and improve its grid-connection capacity, the capacity based application of photovoltaic power generation and the power based application of wind power are generally adopted in the configuration of electrochemical energy storage. The configuration of electrochemical energy storage mainly includes the following functional services and application directions. In the actual project, it is generally the comprehensive application of several functions.

1) ensure continuous and stable output

By calming down the output, the energy storage system can quickly recharge and discharge to adjust the power when the wind power/photovoltaic power changes with the situation of environmental resources or the unstable performance of the equipment leads to the power fluctuation, so as to realize the smooth and stable power. According to the actual characteristics of regional power fluctuations, energy storage types, power, capacity and corresponding control strategies should be reasonably selected.

Wind/photovoltaic power station output power to the low credible prediction, via the configuration of a certain capacity of energy storage system can make the output curve of new energy power station according to the plan or schedule instruction, through the control of energy storage battery charge and discharge process, the output plan on different time scales tracking control strategy for effective coordination, the output of the actual power output as close as possible to planning the curve. At the same time, the energy storage system helps to improve the accuracy and pass rate of short-term power prediction and further reduce the assessment caused by large deviation of short-term power prediction. In view of the high fluctuation of output power of wind power generation and the capacity optimization of micro-grid hybrid energy storage system, the multi-stage optimization configuration method of hybrid energy storage capacity is adopted to decompose the mixed energy storage power in stages, and the configuration of hybrid energy storage capacity is carried out according to the decomposition results. Some studies have proposed to decompose the output power of the original wind power based on the wavelet packet, and realize the coordinated flat-slip output power through the coordinated control strategy of energy storage energy management.

2) participate in the power supply frequency modulation/voltage regulation auxiliary service

The battery energy storage system can improve the regulation capacity of new energy output at the power generation side and flexibly adjust the input and output of active and reactive power. Therefore, it can improve the frequency and voltage regulation capacity of the power generation side. It is of great significance to improve the power quality of grid connection.

Through the coordinated control between the energy storage system and the wind turbine, the transient frequency response characteristics of wind power grid connection can be improved. The reactive power in the access network can be compensated locally by using the reactive power and voltage quick regulation function of the energy storage device, so as to solve the voltage fluctuation caused by renewable energy generation. Consider spike characteristics of primary frequency, through the wind rotor inertia release and energy storage steady-state support united coordination control strategy (including one FM in short-term peak power shall be borne by the wind, steady power needed in FM shall be borne by the energy storage system), with the minimum energy storage power configuration of wind power generation the main dynamic support grid frequency modulation of the target.

3) ensure power quality

Through the rapid adjustment of the energy storage system, it can prevent the load fluctuation, voltage drop and other external interference caused by the grid fluctuations on the system to create a
large impact, to ensure the quality and reliability of the power output. The energy storage system can not only guarantee the stability and reliability of the system, but also be an effective way to solve the dynamic electrical energy quality problems such as voltage pulse, inrush current, voltage drop and instantaneous power supply interruption.

4) peak cutting and valley filling

According to the peak and valley characteristics of the system load, it is stored in the low load period. The surplus electricity can also absorb power and energy from the grid (as a reserve capacity within the grid) in conjunction with grid scheduling. The energy stored in the battery is released in the peak load period, so as to reduce the peak-valley difference of the grid load and reduce the power supply burden of the grid. To some extent, it can also make the output of new energy generation more stable in the peak load period. The characteristics of wind power generation and photovoltaic power generation can be used to complement each other. Through the dispatching mode of the wind-storage joint system, the negative peak adjustment capacity limit in the valley period of the system can be taken as the target. Under the minimum energy storage capacity demand, the system stability can be satisfied to realize the maximum absorption capacity of new energy.

In addition, it can realize the recycling and utilization of wind abandoning and light abandoning. In the case of power rationing, the owner's loss of electricity and benefits can be recovered to some extent. However, due to the reason of energy storage cost and the dynamic change of wind abandoning and light abandoning, it is suggested that the utilization of energy storage for recycling and utilization of power abandoning should not be regarded as the main development direction of the new energy generation side.

5. Research prospects

With the increase of new energy capacity and quantitative configuration stored energy policy, the future of energy storage in new energy power generation side will further expand the application scope and scale, the function will be more rich, but the electrochemical energy storage is still exist many problems to be solved, such as battery production cost is higher, unsafe, lack of the new energy and the energy storage application effective incentive, the problem such as the height of the fusion technology. Therefore, in order to meet the rapid and healthy development demand of energy storage system in the new energy generation side, it is suggested to start from the study was conducted in the following four areas.

1) the current battery ontology technology comes from power battery, so it is necessary to develop the energy storage technology suitable for the large capacity and high power application of the new energy generation side. At the same time of reducing the manufacturing and application costs of the energy storage system and equipment, in-depth optimization research shall be carried out on the adaptability of the established application scenarios. It is a trend to develop new electrochemical energy storage battery products with high conversion efficiency, long life, high safety performance, large capacity and suitable cost.

2) in the future, the energy storage function of the new energy generation side will tend to multiple comprehensive services, so batteries with comprehensive performance of power type and capacity type are required. On the one hand, it can be realized by researching and developing the battery itself. On the other hand, the performance complementary research of the two energy storage technologies can be utilized to realize the comprehensive functions. For example, the hybrid energy storage of ultracapacitors and capacity batteries can realize the comprehensive functions of power and capacity.

3) on the basis of matching batteries, carry out high integration of frequency/voltage regulation between wind power and energy storage to complement each other. Research on targeted and refined control strategies to achieve accurate control and application of energy storage.

4) research on the comprehensive evaluation technology and method of energy storage system. The four-dimensional evaluation is carried out from the aspects of safety, electrical performance, scene adaptability and economy, and the comprehensive evaluation of the energy storage system is realized by combining with the research of detection technology and evaluation indexes.
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