Research on Energy Storage Development Adapting to Large-scale Access to Renewable Energy

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Abstract. Energy storage is the key technology for large-scale renewable energy access and energy Internet construction. Among the numerous energy storage technologies, the pumped storage and electrochemical energy storage are the fastest developing. In the paper, the present application status of the pumped storage and electrochemical energy storage is introduced. In this paper, the development prospect of energy storage and its impact on power system are analyzed, and the overall strategies and ideas to deal with the development of energy storage are put forward.

1. Introduction

Development status. The energy storage industry is developing rapidly along with energy storage technology matures in China. The energy storage industry is gradually transitioning from R&D demonstration to commercial application stage. Energy storage technology can be divided into five types: physical (mechanical), electrochemical, electromagnetic, thermal and chemical energy storage according to different energy conversion methods.

![Classification of energy storage](image)

- **Pumped storage**
- **Compressed air energy storage**
- **Flywheel energy storage**
- **Lead carbon battery**
- **Lithium battery**
- **Flow battery**
- **Superconducting magnetic energy storage**
- **Supercapacitor**
- **Hydrogen production by electricity**
- **Electrosynthesis of natural gas**

Pumped storage is the main energy storage power source in China. The scale of energy storage is 32.4GW by 2019. The installed capacity of pumped storage is 30.3GW, accounting for 93.5% of the total installed capacity of energy storage. Electrochemical energy storage is 1710MW, the ratio is 5.3%

Pumped storage is more economical, and other energy storage technologies are more expensive. The unit investment cost of pumped storage is 30% to 50% of other electrochemical energy storage, and its life span is 3 to 5 times. Lead-carbon batteries are more economical in...
electrochemical energy storage, the cost of the battery body has been reduced by 45% since 2010. However, the unit investment cost is still 2.4 to 12 times of flexible transformation of thermal power and 1.6 to 3 times of gas power.

The characteristic of energy storage technologies is different, and low cost, long life, high safety, large capacity, and recyclability are the main development directions. All kinds of energy storage technologies are different in energy conversion efficiency, continuous charge, discharge time, response speed and other indicators. The pumped storage life and continuous charge discharge time are longer, while the response speed is relatively slow which requires higher geographical environment. The response speed of electrochemical energy storage is faster, while short service life. Electrochemical energy storage has a great potential safety hazard with the increase of battery energy density and power density.

| Energy storage technology | Energy conversion efficiency(%) | Continuous discharge time | Number of cycles & service length | response speed | Environmental protection |
|--------------------------|---------------------------------|---------------------------|----------------------------------|----------------|--------------------------|
| Pumped storage           | 70-80                           | 6-12 hours                | >50 years                        | Per minute     | pollution-free            |
| Lead carbon battery      | 70-85                           | Second-hour               | 3700-4200 times                 | <10 ms         | lead pollution            |
| Lithium battery          | 90-95                           | Second-hour               | 3000-15000 times                | ms             | residual pollution        |
| Vanadium flow battery    | 75-85                           | Second-hour               | 10000-15000 times               | ms             | pollution-free            |
| Sodium sulfur battery    | 80-90                           | Second-hour               | 4500 times                      | ms             | residual pollution        |

The pumped storage industry chain is relatively mature in China, which is mainly invested and operated by power grid enterprises. Electrochemical energy storage industry chain is gradually clear. Electrochemical energy storage gradually forms the whole industry chain of ‘raw material production integration application recovery’. There are still many problems, such as the lack of battery, energy management system (BMS), converter (PCS) and other products to meet the needs of power grid high-power applications; the lack of relevant standards for grid connection, dispatching operation, security and so on; the lack of reasonable electricity price, cost accounting and recovery mechanism.

![Figure 2. Electrochemical energy storage industry chain](image-url)
2. Development prospects

Prospect of energy storage development. It is estimated that the national energy storage scale will reach 200 million kilowatts by 2035. The installed capacity of pumped storage is 140 million KW considering the peak load regulation and frequency regulation of the system, renewable energy consumption demand and resource development progress of the station site. Non pumped storage 65 million kW.

Improving the regulation capacity of coal-fired power plants can significantly reduce the demand for energy storage that the comprehensive cost is lower than renewable energy storage. Coal power flexible transformation is the first choice. In the future, pumped storage will develop rapidly, and the proportion of non pumped storage will gradually increase. It is estimated that pumped storage should be developed first before 2035, compared with non pumped storage, the technology economy will still have a greater advantage. Non pumped storage is more suitable for distributed and small-scale applications. Decentralized energy storage will develop rapidly before 2035, the total scale of centralized energy storage will gradually exceed that of decentralized energy storage after 2035. It is estimated that the proportion of pumped storage, centralized energy storage and decentralized energy storage will be about 4:1:1 in 2035 and 1.3:1:1 in 1950.

The proportion of the western and northern regions will continue to increase. In terms of pumped storage, the eastern and central regions are less difficult to develop and relatively rich in station resources. It is estimated that 71% of pumped storage energy will be distributed in the eastern and central regions in 2035; the pumping and storage development speed in the western and northern regions will be accelerated after 2035, and the proportion of the eastern and central regions will be reduced to 63% by 2050. In terms of non pumped storage, mainly in the eastern and central regions with higher electricity price bearing capacity with the western and northern regions accounting for 33% by 2035; The consumption demand of centralized renewable energy in the western and northern regions will grow rapidly after 2035, and the proportion of non pumped storage energy will increase to 54% by 2050.

| Region       | 2035      | 2050      |
|--------------|-----------|-----------|
| Pumped storage | 4000      | 10000     |
| Non pumped storage | 2170     | 4330      |
| Total installed capacity | 6170   | 14330     |
| Proportion     | 30.1%     | 69.9%     |
| Pumped storage | 6000      | 10000     |
| Non pumped storage | 13600    | 11400     |
| Total installed capacity | 19600  | 21400     |
| Proportion     | 47.8%     | 52.2%     |

Figure 3. Proportion of installed capacity of various types of energy storage in 2020-2050
3. Influence of future energy storage development on power system

3.1. Influence of energy storage development on power system

Energy storage operation mode. Energy storage should be changed from following load or renewable energy operation to following net load curve. The operation mode of energy storage should match with the change of net load curve. During the peak period of net load, the system will be discharged and charged during the low period. Most of the charging power comes from renewable energy and hydropower, and some of the charging power comes from thermal power from the perspective of the most economic operation of the whole system in the future high proportion of renewable energy power system.

Relationship between energy storage and renewable energy development. Energy storage is not the more the better as the flexible power supply which reasonable energy abandonment by renewable energy can help to achieve the lowest overall cost of the system. If the energy abandonment rate is too high, it will lead to the waste of renewable energy resources and equipment. If the energy abandonment rate is too low, it will lead to the new construction of a large number of energy storage and other regulatory resources in order to absorb the small proportion of peak electricity, and the marginal cost is very expensive.

If the scale of wind power and solar power generation is 700 million and 650 million kilowatts by 2035, the energy rejection rate should be controlled below 5%, energy storage demand is 250 million kilowatts and the total cost of power supply in the corresponding planning period is 33.7 trillion yuan. If the security and economy of the system are fully considered, the energy abandonment rate will be increased to about 8%, the energy storage demand will be reduced to 200 million kilowatts, and the total cost of power supply will be reduced to 33 trillion yuan; While the energy rejection rate is higher than 8%, the total cost will increase. Therefore, considering the lowest total cost of the system, the reasonable energy abandonment rate will be about 8% by 2035, and the corresponding installed energy storage capacity will be 200 million kilowatts.

Energy storage can effectively reduce the waste wind and light, and promote the clean substitution of renewable energy for thermal power. In 2035, the energy storage can support 210 billion kWh of renewable energy consumption, and the energy abandonment rate can be reduced by 8.8% compared with the scenario without energy storage. At the same time, energy storage can reduce the demand of thermal power installed capacity and improve the utilization efficiency of thermal power. Considering the consumption of renewable energy of the same scale, if the scale of energy storage is reduced by 30 million kilowatts, the installed capacity of thermal power will be increased by 60 million kilowatts and the utilization hours will be reduced by 200-300 hours.

Figure 4. Renewable energy consumption in 2035
3.2. The relationship between energy storage and power grid development

Energy storage can be used as the regulator and stabilizer for large-scale trans regional power transmission, and enhance the rapid support capacity of active/ reactive power of power grid. It is estimated that the energy storage in the sending end area will provide 130 million kilowatts of flexible regulation capacity in 2035, which can provide 220 million kilowatts of fast active and reactive power support in the receiving area to effectively deal with large-scale trans regional transmission failure.

Trans regional power transmission and energy storage can replace each other. Trans regional power transmission can enhance the complementary peak load regulation among regions and replace the flexible regulation of energy storage. In 2035, the scale of energy storage demand will decrease by 9.7% or increase by 16% respectively while the scale of power flow increases or decreases by 20%.

4. conclusion

Traditional power planning mainly focuses on the balance of power and quantity. In the future, the improvement of flexible regulation capacity will be the important part of power planning and operation. The first is the flexible transformation of thermal power, which is a power source with great potential for flexible regulation. The second is to speed up the development of pumped storage. It is estimated that the competitiveness of pumped storage will still be stronger than other energy storage methods before 2035. The third is orderly development of non-pumped storage energy, considering market factors, appropriate development of non-pumped storage energy.

References

[1] YAN Xiaohui, XU Yujie, JI Lyu, et al. Forecasting and analysis on large-scale energy storage technologies in China. Electric Power, 2013, 46(8): 22-29.

[2] LI Jianguo, JIAO Bin, CHEN Guochu. Sodium sulfur battery and its application. Journal of Shanghai Dianji University, 2011, 14(3): 146-151.

[3] Tian Shiming, Luan Wenpeng, Zhang Dongxia, et al. Technical forms and key technologies of energy internet. Proceedings of the CSEE, 2015, 35(15): 3482-3494.

[4] Zhang Jun, Dai Weiyi. Overview of international roadmap studies on energy storage technologies. Energy Storage Science and Technology, 2015, 4(3): 260-266.

[5] Zhang Chuan, Yang Lei, Niu Tongyang, et al. Comparison and analysis of energy storage technology to balance fluctuation of wind power output. Power System Protection and Control, 2015, 43(7): 149-154.