Economic analysis of distribution network planning considering decentralized energy storage system

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Abstract. The rapid development of renewable energy makes the power grid gradually change from traditional power system to high proportion renewable energy power system. The rapid development of electric vehicles, energy storage and controllable load increases the uncertainty of load. The flexible adjustable load is less, which can not meet the consumption demand of large wind and solar power generation, and can not support the power valley filling demand when the wind power output is insufficient. Energy storage system is very important for the safe and stable operation of renewable energy internet. How to consider the reliability and economy, this paper proposes a distribution network planning scheme considering energy storage system.

1. Introduction

The energy storage system is very important for the safe and stable operation of renewable energy Internet[1]. Among them, the power type energy storage represented by super capacitor and flywheel can release a lot of power in a short time, with long cycle life, and can support the stable operation of the system in case of load impact or rapid fluctuation of new energy; the energy type energy storage represented by lithium battery, pumped storage, compressed air and so on is dense[2].

It can store a large amount of electric energy for continuous power supply when the new energy power supply is insufficient, and when the new energy consumption is insufficient, the role of different types of energy storage in the system is different, so it is necessary to optimize the combination[3-4]. At the same time, centralized and decentralized energy storage have different local and global impacts on the system[5]. How to take into account the reliability and economy, under the condition that the investment cost of energy storage system is reasonable and acceptable, the reasonable allocation of energy storage type, location and capacity is the basis to ensure the safe, stable and sustainable economic operation of power grid and meet the needs of users[6].

Centralized energy storage has a large investment and slow development. In the future, energy storage of power grid will develop in a variety of forms, decentralized layout and multi investment subjects. The state of distributed energy storage system is different, the state of charge (SOC), capacity configuration, maximum charge and discharge power are different, and even the operation state of different energy storage units in the same power station is not the same[7].
The lack of effective coordination and control means between these decentralized heterogeneous energy storage systems, and the enthusiasm of a large number of decentralized energy storage to participate in the power grid regulation is not high, resulting in single energy storage power station capacity is idle and cannot be fully utilized\cite{8}. Facing different application scenarios, considering the battery operation status and control effect, according to the different states of these energy storage units, the distributed energy storage coordinated control strategy is needed to coordinate and optimize the control process.

2. Application scenarios of energy storage system

The application of energy storage technology can be roughly divided into power supply side, power grid side and user side. In the power supply side, the energy storage system can help to provide secondary frequency regulation auxiliary services, improve the AGC Capacity of thermal power units, absorb the fluctuation of renewable energy power generation, smooth the output curve, and improve the controllability of renewable energy generation scheduling.

On the power grid side, the energy storage system can ease the power supply bayonet, participate in peak load regulation, frequency modulation, black start and other auxiliary services.

On the user side, the main application scenario of energy storage system is based on the difference between peak and valley electricity prices, the use of energy storage products "low charge, high discharge" to achieve arbitrage, and large industrial users can save capacity electricity charges, but also can improve the reliability of local power supply.

3. Economic analysis of distribution network planning

There are 16 of 110kV substations and 16 of 110kV lines in a certain area, 14 of 35kV substations and 23 of 35kV lines. The maximum load occurred in July and the minimum load occurred in February, all of which were new energy installations, with wind power accounting for 60% and photovoltaic accounting for 40%.

Figure 1. The sketch diagram of distribution network in a certain area.

When the wind power generation is large, there is a main transformer feeding bayonet of 18MW. By considering the constraints of IGBT and capacitor characteristics, the minimum value of \( N_{st} \) is presented as

\[
N_{st, \text{min}} = \frac{M_{i}M_{U}U_{\text{ref}}}{\sqrt{2}M_{i}^{2}P\left(\frac{T}{C_{p}}+R_{p}\right)} \leq \frac{2(M_{i}M_{U}U_{\text{ref}})}{2M_{i}^{2}P\left(\frac{T}{C_{p}}+R_{p}\right)} \leq \frac{2M_{U}P_{\text{max}}U_{\text{ref}}}{M_{i}^{2}M_{U}P_{\text{max}}\left(\frac{T}{C_{p}}+R_{p}\right)}
\]

the maximum value of \( N_{st} \) is expressed as
According to 90% of the maximum discharge depth of lithium battery energy storage system, the area needs to be equipped with 20MW / 40MWh energy storage system to solve the problem. As mentioned above, under normal operation mode, 110kV line a has 3MW bayonet; under N-1 mode, 110kV line B has 2MW bayonet, 110kV line C has 2MW bayonet.

**Solution of energy storage system:** Based on the above analysis, it is recommended to adopt the technical scheme of "distributed layout, modular design, unit access and centralized control", and configure a set of 10MW / 20mwh energy storage system in 110kV substation a, a set of 5MW / 10mwh energy storage system in 110kV substation B, and a set of 5MW / 10mwh energy storage system in 110kV substation C. According to the unit cost of 2000 yuan / kWh, the total capacity of energy storage system is 20 MW / 40 MWh, and the cost of battery prefabricated cabin is about 80 million yuan.

**Conventional project solution:** 110kV substation a expands a main transformer and transforms 110kV line a and 110kV line B, with a total cost of about 50 million yuan.

**Comparison of the two schemes:** as the unit cost of the energy storage system is reduced year by year, according to the preliminary calculation, the cost ratio between the energy storage system and the conventional power transmission and transformation project in this area is about 1.6:1. Although the price difference is not very large, the conventional power transmission and transformation project can meet more new energy transmission, and the energy storage system margin is relatively small. When the energy storage system runs at full power for two hours, the line loss of wind power at 110-220kV network level is about 0.8mwh, but the energy storage system's own operation power loss is about 4mwh (calculated according to the operation efficiency of lithium battery energy storage system is 90%), so the operation loss is relatively large.

4. Conclusion

**Energy storage at power supply side:** for the red warning area of new energy consumption, it can guide new energy power plants to realize grid connection by configuring energy storage system. Owners can build energy storage by themselves, or carry out energy storage construction through contract energy management mode, and share the benefits.

**Energy storage at power grid side:** under the condition that the cost of power transmission and transformation project is not different from that of conventional power transmission and transformation projects and there are investment channels, small-scale pilot construction can be carried out, and experience in planning and construction, dispatching control, operation evaluation of energy storage system can be mastered.

**Energy storage at user side:** Taking the integrated energy service company as the starting point, actively carry out the application of high reliability power supply on the user side, peak shaving and valley filling, optimize the business environment, seize the energy storage market on the user side, and feed back to support the high reliable operation of the power grid.

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