Key Technologies and Applications of Cloud Energy Storage

Yanping Zhu*, Ping Wu, Huanhuan Fang, Yueguang Zhang, Fei Xie
State Grid Shanghai Fengxian Electric Power Supply Company, Shanghai, China
*Corresponding author e-mail: zhuyanping_09@163.com

Abstract. Due to the fluctuation of electricity market price and intermittence of new energy generation, the demand for energy storage in the power system is also increasing. However, due to the high cost of energy storage construction and the long payback period of investment, users are not willing to build energy storage. Cloud energy storage is one of the development directions of energy storage in the future. This paper introduces the definition, characteristics and research status of cloud energy storage in detail, analyzes the relationship between cloud energy storage and distributed energy storage, summarizes the key technologies and business models of cloud energy storage, and prospects the future development of cloud energy storage.

1. Definition, characteristics and current situation of cloud energy storage

1.1. Background

In recent years, with the increasing social attention to the ecological environment, the proportion of wind power, solar energy and other clean energy generation is also gradually increasing. However, due to the large influence of climate conditions on renewable energy power, its output is uncertain and intermittent. When a large number of renewable energy power is connected to the power grid, it will have an adverse impact on the power quality of the grid and the reliability of power supply, and at the same time, it will also cause substantial fluctuations in the real-time electricity price of the system. In view of this problem, energy storage devices are widely used to realize the stabilization of fluctuation. In addition, for a large number of distributed new energy sources, a large number of distributed energy storage devices are also required to solve the mismatch between user demand and power output time.

Although distributed energy storage on the user side plays an increasingly important role in solving power grid structural problems, the current distributed energy storage access and output have the characteristics of decentralized layout and poor controllability. From the perspective of power grid scheduling, there is currently a lack of effective scheduling means. For example, spontaneous operation is equivalent to access to a large number of random disturbance power sources, whose disordered operation is not conducive to the improvement of power grid frequency, voltage and power
quality, and also causes a large waste of energy storage resources [1]. From the user's point of view, the energy storage device has a high cost, a large investment for the user, and it is difficult to equip complex prediction, control and communication systems. Therefore, although users have a certain demand for energy storage, the willingness to install energy storage devices is still not strong.

Based on the above situation, literature [2] proposed cloud energy storage technology based on cloud services and sharing economy. This technology not only meets the needs of users for distributed energy storage, but also realizes the efficient management and operation of energy storage while reducing the cost of energy storage for users due to the centralized management of energy storage equipment.

1.2. Definition of cloud energy storage

Cloud energy storage is a kind of Shared energy storage technology based on the established existing power grid. Users can use the shared energy storage resources composed of centralized or distributed energy storage facilities anytime, anywhere and on demand, and pay service fees according to usage requirements [3]. Its structure is shown in figure 1.

![Figure 1. Cloud Energy Storage Structure](image)

In a cloud energy storage system, users first purchase energy storage capacity to obtain distributed energy storage services. After that, the user realizes information communication with the cloud energy storage system through the intelligent terminal, manages the charging and discharging of the purchased capacity, and realizes the two-way transmission of information and expenses. At the same time, the energy transfer between users and energy storage facilities is realized by the grid.

1.3. Characteristics of cloud energy storage

virtualization: in cloud energy storage, the user purchases virtual energy storage capacity from the cloud energy storage provider without installing the energy storage facilities directly on the user's side. At the same time, the energy storage capacity purchased by the user can be directly controlled through the virtual interface of the intelligent terminal to meet the user's energy demand.

user-friendly: cloud energy storage is basically the same as the real energy storage, but it is more convenient to use than the real energy storage, and does not need installation or special management. Therefore, the energy storage facilities do not occupy the space on the user's side, so that some users have the demand for energy storage. However, users without the space for the construction of energy
storage facilities can also obtain the energy storage services. In addition, since all energy storage facilities are installed, managed and maintained by cloud energy storage providers, users only need to arrange charging and discharging of energy storage facilities according to their own energy consumption needs, and there is no need for maintenance and overhaul by users, so users can obtain better energy use experience.

resource sharing: cloud energy storage takes "sharing" as its main value orientation, and improves resource utilization efficiency through users sharing energy storage resources. Specifically, due to the diversity of user types, the demand for energy storage will also generate diversity. The same batch of energy storage resources can be provided to different users in different time periods, so as to maximize the utilization rate of resources and further reduce the construction and operation costs of energy storage resources.

1.4. Development status of cloud energy storage

The concept of cloud energy storage was first proposed by professor kang chongqing [2]. Currently, there are only a few user-side idle capacity Shared energy storage projects, and there is no cloud energy storage engineering practice of self-built energy storage facilities by energy storage providers.

As for the overall research direction of cloud energy storage, professor kang chongqing elaborated the research framework of cloud energy storage in literature [4], and divided the future research content of cloud energy storage into three directions, namely, market main line, operation main line and object main line. Among them, the main line of operation mainly includes three elements: investment planning, operation optimization and technical and economic analysis. The elements of the main object line include users, cloud energy storage providers, retailers and the power grid; Market mainline includes market model, service package and price mechanism. The research of different main lines is not independent, but interrelated and coupled. The contents of different main lines are interrelated and constitute the potential research content of cloud energy storage field in the future.

In terms of the modeling of cloud energy storage system, the literature [4] established the basic model of user operation and the basic model of cloud energy storage provider operation, and realized the mathematical description of the operation mode of cloud energy storage, which is of great reference value to the subsequent research on cloud energy storage. Literature [5] proposed a model of social benefits of annual investment in computing cloud energy storage, through which the social benefits brought by the reduction of energy storage facility construction costs after the use of cloud energy storage were quantified. Literature [6] established a user collaborative optimization model for a community integrated energy system including Shared energy storage. Literature [7] proposed a Shared energy storage mechanism for new energy plants on the power generation side, and established a Shared energy storage planning model based on cooperative game. The participants of the game are each new energy power plant. The participants decide how to participate in the game by comparing their own benefits in different cooperation modes.

In terms of the sharing and utilization of existing idle energy storage, literature [8] proposed centralized control and management of idle capacity of multiple household energy storage devices to make them become storage facilities of cloud energy storage based on the current situation of large installed amount of household energy storage facilities but low utilization rate in Germany. This theory can achieve a certain capacity of cloud energy storage services without additional installation of new energy storage facilities. Ron d. Rappaport et al. analyzed the feasibility of idle capacity sharing
of household energy storage batteries in the UK, and analyzed the profitability of implementing aggregation sharing of household batteries in the UK in consideration of operation mode, economy and technical characteristics [9].

In practical engineering application, in 2018, Guangzhou power supply bureau cooperated with tower company to build the first power storage demonstration project of distribution network for idle battery utilization of communication base station in China. Project choose 56 straight power supply mobile base stations, the use of idle standby energy storage resources, each base station of large-scale distributed battery systems, energy in the Internet, on the basis of big data and cloud platform, through modern means of communication, each distributed base station energy storage system for monitoring and management, implement demand side load and rapid interaction between response of the energy storage system, optimize energy in ensuring the rational allocation of demand side [10].

2. Relationship between distributed energy storage and cloud energy storage

Compared with distributed energy storage, cloud energy storage achieves the same purpose of use as distributed energy storage -- eliminating the intermittence of some new energy generation and the fluctuation of electricity market price. On the basis of this, it also improves the utilization rate of energy storage equipment, reduces the cost of energy storage, and enables more users with energy storage needs to obtain energy storage services. Therefore, it is essentially an alternative to distributed energy storage. Currently, cloud energy storage is mainly divided into two types. One is the initial phase of cloud energy storage in which users own the energy storage device and share the energy storage platform. On the other hand, independent Shared energy storage operators mainly build self-built energy storage facilities, supplemented by leasing existing distributed energy storage resources on the user side, build an energy storage service platform, and provide users with a complete form of cloud energy storage services [7].

2.1. The user’s own energy storage device participates in cloud energy storage

For the user's own energy storage device participating in cloud energy storage, it is equivalent to a new management mode of energy storage device proposed on the basis of distributed energy storage on the user side. Since storage of new energy power requires a large energy storage capacity, and most of the current capacity has a low utilization rate, a lot of energy storage resources are wasted. The idle energy storage capacity of users can be Shared through the sharing platform, which can make full use of user complementarities and improve the utilization rate of energy storage devices. Meanwhile, users can also get additional benefits from sharing their energy storage devices. In addition, since the energy storage facilities are self-built by users, there is no need to build new centralized energy storage devices, which is conducive to promotion.

However, as the energy storage facilities are still scattered among users, there will be inconvenience in management and maintenance. In addition, due to the large number of energy storage devices and scattered, there is also a lot of inconvenience in the interconnection and communication between the devices. Based on the above reasons, cloud energy storage service with existing energy storage facilities can be used as an energy storage solution in the transition stage from distributed energy storage to cloud energy storage, and can also accumulate operational experience for the future cloud energy storage operation mode of self-built energy storage by suppliers.
2.2. **Self-built energy storage by operators**

The self-built centralized energy storage facility of the operator has a large scale, which can make use of the scale effect to obtain a lower unit energy storage investment cost than the distributed energy storage invested by the user, thus reducing the total cost of the cloud energy storage system. In addition, the cloud storage provider can get more than the average user through prediction technology of information, such as electricity price, user more accurate overall charge and discharge requirements, etc., and then based on this information advantage using optimization method is more reasonable and real-time by charging and discharging strategy, so as to promote the cloud storage provider profits, reduce the overall cost of cloud storage system.

For the existing user-side distributed energy storage facilities, the cloud energy storage provider can take them as standby capacity and integrate the user's idle energy storage capacity into the unified cloud energy storage management. On the one hand, the construction cost of energy storage facilities can be reduced; on the other hand, users participating in distributed energy storage can better participate in cloud energy storage.

3. **Key technologies of cloud energy storage**

3.1. **Cloud energy storage planning and configuration technology**

Since cloud energy storage requires energy storage providers to build energy storage facilities, the investment and construction of energy storage facilities should meet the needs of users with the minimum economic cost. Considering the different charging and discharging characteristics of different energy storage devices, it is necessary to reasonably match various energy storage facilities according to the needs of users and make full use of the complementarity of different types of energy storage technologies to maximize benefits.

For users, since the energy storage capacity leased from the energy storage provider needs to be independently determined, the evaluation of their own energy consumption and the decision-making method of energy storage capacity are one of the key technologies for users to participate in cloud energy storage.

The literature [11] put forward a consideration of the characteristics of different kinds of energy storage battery energy storage system heterogeneous storage technology, based on lead-acid batteries, lithium ion battery, oxidation also influent flow batteries, sodium sulfur battery of these four battery charge and discharge characteristics of their respective, proved by calculation using multiple types of cloud storage battery system compared with using a single energy storage system has a better economy, and puts forward the economy analysis method for heterogeneous storage system.

In terms of the determination of user energy storage capacity, literature [12] proposed a capacity determination method for home cloud energy storage service, which could determine the required cloud energy storage capacity according to the user's energy use characteristics.

3.2. **Cloud energy storage service pricing technology**

Price is a key factor for whether users participate in cloud energy storage. When determining the price, the cloud energy storage provider should enable users to obtain certain benefits compared with the case of not using cloud energy storage, but at the same time ensure the interests of the provider.
Therefore, reasonable pricing mechanism of cloud energy storage is an important guarantee for the development of cloud energy storage.

In current studies, pricing methods of cloud energy storage are mainly divided into three categories: pricing according to capacity, pricing according to traffic and pricing according to package [3]. Among them, capacity pricing means that users purchase the right to use cloud energy storage capacity from the energy storage provider on demand according to the price of cloud energy storage unit capacity and power provided by the provider. Pricing according to the traffic is similar to the Internet model. User fees are charged according to the amount of charging and discharging of the cloud battery each time, which can effectively avoid unreasonable charging and discharging demands of users. Through the analysis of user data, different cloud energy storage packages and reward and penalty measures can be formulated for different types of users, so as to guide users to use energy storage resources according to the wishes of energy storage providers and further improve the utilization efficiency of energy storage facilities.

3.3. Cloud energy storage operation and control technology

The operational goal of cloud energy storage providers is to minimize operating costs while meeting users' charging and discharging needs. Since users' demand for cloud energy storage services is mainly to charge and discharge according to their own arrangement, and cloud energy storage providers have a large number of energy storage resources, they do not need to completely manage the charge and discharge according to the charge and discharge requirements of each user, but choose an appropriate time to control the charge and discharge of energy storage facilities. Therefore, providers need to master big data analysis and prediction technology to predict users' charging and discharging demands and future electricity price trends, so as to obtain more reasonable charging and discharging strategies.

At the user level, compared with distributed energy storage, cloud energy storage users will have larger energy storage capacity. Therefore, how to effectively utilize cloud energy storage capacity and make reasonable charging and discharging decisions are key technologies for cloud energy storage users.

The literature [5] studies the decision-making mode of the provider and the user, and establishes the operational decision-making model of the user and the energy storage provider respectively with the goal of minimizing the purchase and use cost of the user's energy storage resources and minimizing the operating cost of the provider's investment. Literature [13] proposed a cost minimization algorithm based on arbitrary threshold price, and based on the fluctuation of electricity price and intermittently distributed generation, the operation mode of cloud energy storage was optimized and calculated.

4. Physical architecture of cloud energy storage energy management platform

The main functions of the cloud energy storage energy management platform are to monitor the running status of user-side energy storage equipment or system, perform demand response business, manage user-side file information and business data at the same time, and provide energy storage energy information access service with portal system. The system design needs to take advantage of platformization and modularization to ensure the compatibility and expansibility of the system. The
The functional architecture of distributed energy storage system based on energy cloud management platform is shown in figure 2.

**Figure 2. Functional Architecture of CES Management Platform**

The cloud energy storage energy management platform has the functions of realizing all energy storage devices within the jurisdiction of the platform, including centralized and distributed energy storage cluster management and multi-objective optimization control, protection and monitoring, communication, data measurement and collection, historical data storage and analysis, and economic calculation, etc.

4.1. **Energy optimization scheduling, operation and maintenance of cloud energy storage**

It includes medium and long-term operation plan, life evaluation, maintenance plan of cloud energy storage, and multi-time scale energy optimization under different scenarios, such as day-ahead optimization and real-time optimization.

4.2. **Coordinated control of cloud energy storage**

Power flow control, active power control, voltage/reactive power regulation, off-grid switching, energy storage system coordination and control functions. The user can control the charging and discharging of the battery system through the cloud platform and set the charging current without the need for operation and maintenance personnel to operate on the site.

4.3. **Protection and monitoring**

Read various information of the equipment, monitor the running situation of the system in real time, make comprehensive judgment and coordinate the running of the system. The available information includes the state, voltage, current, power of the entire battery system and the state, voltage, SOC of the individual battery.
4.4. Historical data acquisition

The cloud platform can store the collected battery system and various states and data of individual batteries. Users can specify the target and time interval to obtain these historical data in the form of original data, histogram, curve, etc. Intuitive data can be obtained through the graphical interface in the client side. Users can also reprocess the data, analyze the data, extract patterns, and provide data support for various assessments and scientific decisions.

4.5. Other functions

Economic and environmental benefit reporting function. According to the stored data, it can calculate the economic benefits brought by various services that izumo energy storage participates in, so that users can know the economic and environmental returns of investment and master the economic situation of the system at any time.

Equipment uses environment report. Report the working environment of the equipment in real time, such as whether the power supply is normal or not, the battery life of the energy storage equipment and other information, so that the user can know the environmental status of the equipment anytime and anywhere.

Journal function. The main information and operation information of the system can be saved.

In addition to the above function, cloud storage energy management platform control system to provide users with virtual machine total life cycle management, provide remote application based on the handheld device APP, providing automated operations and automatic alarm, offers a variety of cloud storage way, allow the user to simplify cloud storage equipment maintenance and extension, focus on core business.

5. Cloud energy storage business model

As a new generation of energy storage scheme based on sharing economy, cloud energy storage has the most significant feature that users can obtain energy storage services without building energy storage facilities. Therefore, there are some differences between its business model and the current energy storage business model.

5.1. Target customer groups

At present, a large number of household and small business users are willing to reduce their energy consumption costs through energy storage [3]. However, due to the small demand for energy storage by a single user, the existing distributed energy storage scheme that users install energy storage devices by themselves is not suitable for such users. Therefore, such users are the main customer group of cloud energy storage.

5.2. Service process

The cloud energy storage provider determines the demand capacity of energy storage facilities by analyzing the electricity consumption data of users in the planned service area, and invests in the construction of centralized energy storage facilities and leases the established distributed energy storage resources. After the facility is put into operation, the provider shall set the service price of cloud energy storage. Users with energy storage needs shall determine the required capacity of cloud energy storage according to the service price of cloud energy storage, and send charging and discharging instructions of cloud energy storage equipment to the cloud platform according to their
own electricity demand. The provider integrates the charging and discharging requirements of all users, and makes decisions on the operation of energy storage facilities, as well as the purchase and sale of energy, so as to meet users' requirements with the minimum operating cost.

5.3. Settlement method

Users first pay a certain fee according to the price or package set by the operator to obtain the right to use the cloud storage capacity. When the user issues a charging order, the energy storage facility will be charged according to the electricity price of the power market at this time, and the electricity purchase fee will be charged by the provider to the user. In addition, the provider can either purchase electricity directly from external sources to charge the battery, or distribute the electricity previously stored when the price is lower to customers, thus generating additional revenue. When the user issues discharge instructions, the provider shall discharge according to the power and time specified by the user, and the provider shall not charge the user for discharging. When the discharge power is greater than the real-time power consumption of the user, a reverse transmission of power to the grid will occur, and the resulting electricity sale proceeds shall be paid by the provider to the user. When the energy storage state of the provider cannot meet the user's discharge requirements, the power grid shall be purchased. The whole settlement sequence of cloud energy storage is the settlement between the user and the provider and the power grid, and then the user and the provider can settle the settlement directly.

5.4. Source of profit

Due to the large number of users, charging and discharging requirements of different users are different. Based on the complementarity between users, the total capacity of the energy storage facilities of the supplier can be less than the total capacity purchased by all users. Therefore, the difference between the capacity invested by the supplier and the capacity purchased by the user provides profit space for the supplier. In addition, due to the provider has the size advantage, and grasp a large amount of data and the user can use the data grid operating, so providers can not only use less cost to manage energy storage facilities maintenance, can also through the large data analysis technology can use to users and grid electricity price forecasting, thus ahead of charging and discharging energy storage facilities, to earn the price difference due to price fluctuations.

6. Conclusion

There have been many typical cases of the application of sharing economy in other fields. As the product of the combination of sharing economy and power system, cloud energy storage has many advantages compared with the current energy storage mode. The development of cloud energy storage can also strongly promote the development of micro-grid, energy Internet and other related fields. This paper introduces the definition, characteristics, key technologies and business models of cloud energy storage in detail. With the increasing attention and research on cloud energy storage, the gradual maturity of cloud energy storage technology and the application and popularization of 5G communication technology with higher speed and lower delay, it will be possible to transform the concept of cloud energy storage into engineering practice, and then cloud energy storage will usher in a broader development prospect.
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