Research on the Orientation and Application of Distributed Energy Storage in Energy Internet

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Abstract. Energy storage is indispensable resources to achieve a high proportion of new energy power consumption in electric power system. As an important support to energy Internet, energy storage system can achieve a variety of energy integration operation to ensure maximum energy efficiency. In this paper, firstly, the SWOT analysis method is used to express the internal and external advantages and disadvantages of distributed energy storage participating in the energy Internet. Secondly, the function orientation of distributed energy storage in energy Internet is studied, based on which the application modes of distributed energy storage in virtual power plant, community energy storage and auxiliary services are deeply studied. Finally, this paper puts forward the development strategy of distributed energy storage which is suitable for the development of China's energy Internet, and summarizes and prospects the application of distributed energy storage system.

Keywords. Distributed energy storage; energy Internet; function orientation; application mode; development strategy.

1. Introduction

In order to adapt to the rapid development of distributed power, the state attaches great importance to the construction of integrated energy system, which characterized with distributed new energy, and energy Internet has become a new research hotspot. Energy Internet is a technology which uses advanced power electronic technology and information technology, interconnecting a large number of energy nodes consist of distributed energy collection devices, distributed energy storage devices and various types of load energy to achieve efficient, clean and safe energy. In energy Internet, a large number of renewable energy and distributed energy will be introduced, and micro-grid and electric vehicles will be universal implicated. As a result, energy storage system will be the key technology to coordinate these applications [1, 2]. It can be used to crack the synchronism of energy production and consumption, making energy translatable in time and space [3-5], which is the premise to achieve energy sharing. It can also be used to solve the uncertainty and disorder of energy flow in energy Internet, to ensure the stability and safety of the system.

The existing researches on distributed energy storage mainly focus on the application of technology and economic assessment, capacity optimization and application development mode in micro-grid,

while researches on distributed energy storage application mode under energy Internet background are few. Based on the SWOT analysis of the energy storage development under energy Internet background, combined with the natural compatibility between distributed energy storage and energy Internet, this paper studies the function orientation and application modes of distributed energy storage in energy Internet. Also, paper puts forward the development strategy of distributed energy storage which is suitable for the development of China's energy Internet, to promote it to develop to the direction of benefiting to energy Internet.

2. SWOT Analysis of Distributed Energy Storage under Energy Internet Background

Clearing internal and external advantages and disadvantages of distributed energy storage participating in the energy Internet is beneficial to promote more coordinated development of the distributed energy storage and the energy Internet. The SWOT matrix for energy storage development under energy Internet background is shown in Table 1.

Table 1. SWOT matrix for energy storage development under energy Internet background

Strengths(S)	Weaknesses(W)
(1)Growth is fast and development potential is great (2)Technical species is relatively rich (3)Government attach high attention	(1)Cost is relatively high and utilization rate is limited (2)Technical route is not yet clear (3)Market mechanism policy is relatively inadequate
Opportunities(O)	Threats(T)
(1)Energy storage has a specific role and demand in the energy Internet (2)Energy storage industry is expected to obtain further external support	(1)The potential penetration of foreign potential competitors (2)Energy Internet development strategy bring external pressure on the energy storage industry

According to the S and O terms in the analysis matrix, the internal and external favorable conditions for the development of energy storage come from the benign development of the energy storage industry itself and its natural compatibility with the energy Internet. While the W and T terms of the matrix show that the industry's immaturity, industry's and government's decision-making lack of experience will be a potential obstacle to future development of energy storage in energy Internet.

3. Research on the Function Orientation of Distributed Energy Storage in Energy Internet

Based on the natural compatibility between the development of distributed energy storage and energy Internet, this section studied the function orientation of distributed energy storage in the energy Internet. In the growing energy Internet, renewable energy and distributed energy will be largely introduced, and micro-grid and electric vehicles will be universal applicator, which made energy storage systems become the key technology to coordinate these applications [6, 7]. The specific function orientation of distributed energy storage in the energy Internet are as follows: 1) to promote the main energy transform from fossil energy to renewable energy, which is the core foundation to build energy Internet and promote the development of new energy industry. 2) to break the bottleneck of real-time balance of power system's supplying, transmission and distribution, and provide possibilities for energy sharing and effective transactions. 3) to provide frequency modulation, voltage modulation and energy alternative services for the distributed power generation and micro-grid system, and achieve balance between energy production and consumption in local power grid; 4) to improve the quality and reliability of distribution network; 5) the application of distributed electric vehicles benefits to peak load shifting and flatten load curve.

4. Research on Application Modes of Distributed Energy Storage in Energy Internet

4.1. Application of distributed energy storage in virtual power plant

Virtual power plant (VPP) is based on the analysis of users' needs [8], load forecasting and power generation forecasting [9].It coordinates and manages the distributed energy resources output by making optimal power generation plan. Virtual power plant can not only improve the scheduling difficulty of new energy power generation as well as the impact to the distribution network, but also allow distributed energy to participate in the electricity market operation. As an important part of VPP [10], energy storage systems (ESS) provides an important guarantee for the stable and economic operation of power system by virtue of its rapid power regulation and supply and demand characteristics after large-scale new energy network-connected, and its allocation will affect the operation of the VPP. The typical application mode of Distributed storage in the virtual power plant is shown in Figure 1.

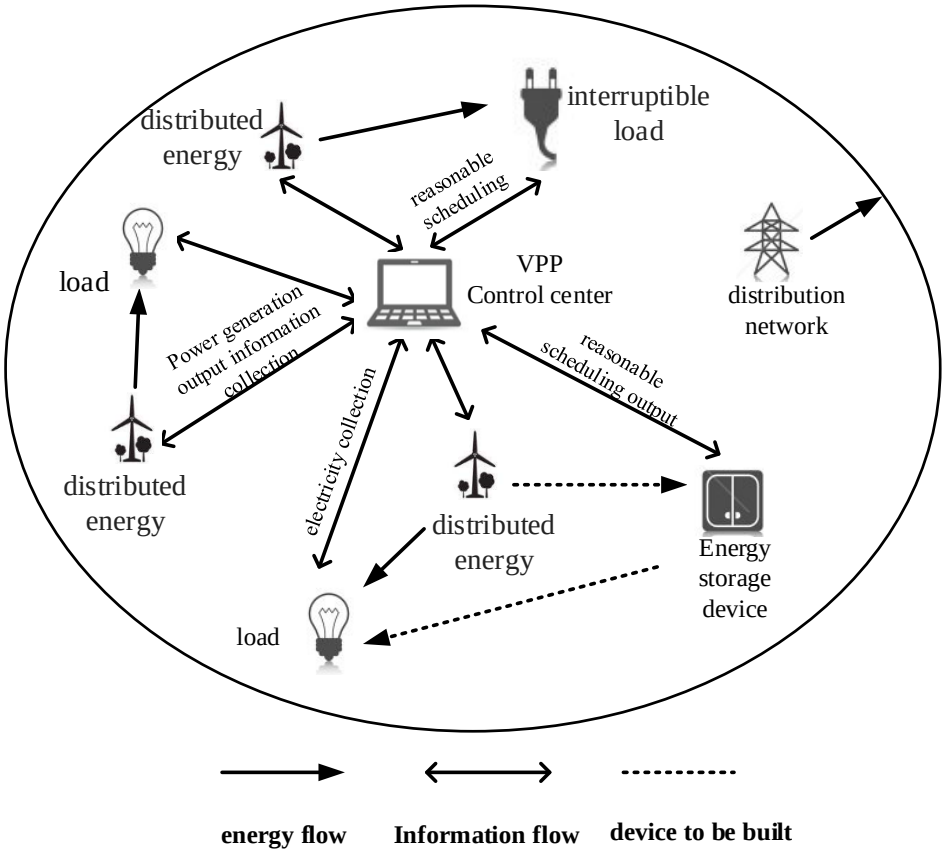

Figure1. Application mode of Distributed storage in the virtual power plant

After adding distributed energy storage, VPP aggregates DG, energy storage unit and interruptible load (electric car, etc.)In a certain area of distribution network via advanced control, metering and communication technology, in order to make its running and resource allocation more reasonable. Under the coordinated control of the control center, the power flow and information flow of the VPP are shown in Fig 1. Specifically, VPP control center can achieve information exchange with the load, distributed energy and distribution network, and process and predict supply and demand information directed to new energy power generation and load electricity information, then reasonably scheduled ESS and

interruptible load as well as other controllable resources output according to market rules, thus completing the economic and stable operation of VPP.

From the VPP application mode, it can be seen that in the case that other distributed energy information is known, the allocation size of distributed storage system is related to the VPP market rules and the effect of ESS on the stable operation of VPP. When large-scale distributed energy is introduced into VPP, it's intermittent and random will have a great impact on the voltage quality of VPP. While distributed energy storage system with supply and demand characteristics can quickly respond and coordinate new energy output, so that to improve the VPP voltage Environment and voltage quality.

4.2. Application of distributed energy storage in community energy storage

Large quantities integrated applications of new energy in user side results in fluctuations of distribution network power, poor power supply reliability and other problems [11]. The application of distributed energy storage to community energy storage can improve the utilization of new energy sources, achieve development of clean and sustainable energy, and meet the requirements of users' various demands including power quality and power supply reliability[12].It can also participate in demand side response to help users change their electricity habits and reduce electricity costs, which will be an effective means to improve the reliability of the load power supply and meet the efficiency, environmental protection, energy saving and low carbon characteristics of wisdom community. Application mode of distributed storage in the community energy storage is shown in Figure 2.

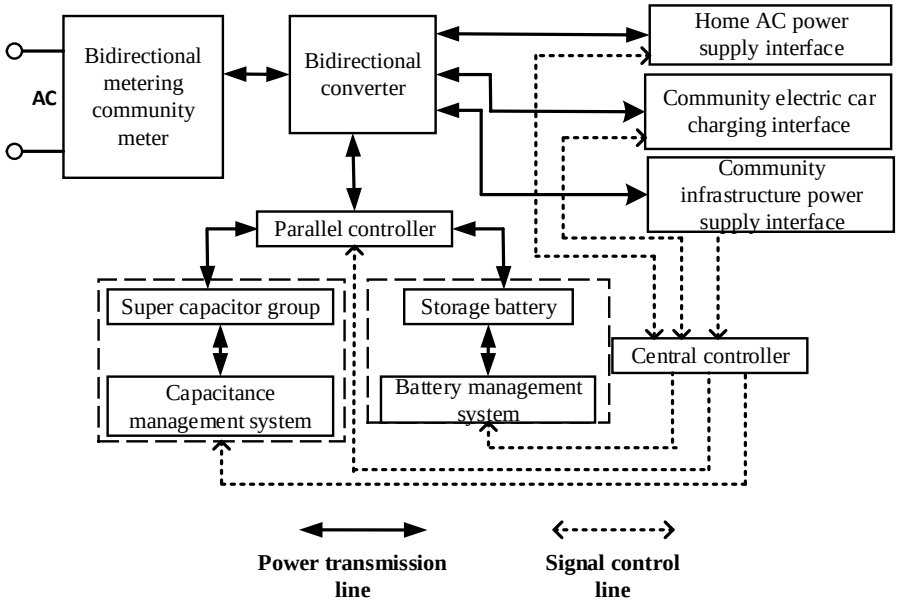

Figure 2. Application mode of distributed storage in the community energy storage

The community energy storage system includes distributed energy storage unit (super capacitor, storage battery and its management system), bidirectional converter, parallel controller and other subsystems. Bidirectional converter is electrically connected with parallel controller, home AC power supply interface, electric vehicle AC charging interface and community infrastructure power supply interface. It is also electrically connected to the energy storage unit to achieve power on-off control between the bidirectional converter and the energy storage unit. Distributed energy storage unit, parallel controller, bidirectional converter, home AC power supply interface, electric vehicle AC charging interface and community infrastructure power supply interface all connect to the central controller electrical signal respectively.

Under the control of the central controller, the parallel controller turns on the bidirectional converter and the energy storage unit to charge the distributed energy storage unit at the off-peak time. When the community needs electricity, the parallel controller turns on the bidirectional converter And the energy storage unit, so that the bidirectional converter can take electricity priority from the energy storage unit, and sent to the home AC power supply interface, electric vehicle AC charging interface for users.

The distributed energy storage system can not only absorb the trough power of the grid, but also be used as a storage unit for a distributed power generation system (such as photovoltaic power generation) (the generated power is introduced into the system by bidirectional metering community meter). Its stored energy can meet the needs of the community daily electricity, and also be used by electric vehicles for fast charging and used as an alternative emergency power, to reduce electricity costs. With connection to the smart grid, distributed energy storage system forms the bidirectional energy flow with the power grid, reaching the goal of peak-load shaving.

4.3. Application of distributed energy storage in user side auxiliary services

With the increasing requirements of power quality and power supply reliability, the user side auxiliary services market obviously needs more and better supporting bodies [13]. Introducing distributed energy storage into the user side auxiliary services, on one hand, can effectively solve the electricity problem in peak, achieve demand side management, and smooth the load, reduce peak and off-peak load difference, reduce electricity costs via load regulation. On the other hand, distributed energy storage can be used as an emergency alternative power supply to avoid the loss of power outages, improving power reliability. In addition, distributed energy storage can also be active and reactive power compensation, make reactive and active instantaneous balance and improve power quality, as a result it can achieve the system's stable operation.

In 2015, the National Energy Board issued *The Notice on promoting electric energy storage to participate in the pilot work of auxiliary services compensation (market) mechanism in "three North" area* [14]. The establishment of a new mechanism for the sharing of auxiliary services, can develop advantages of user side energy storage technology in electric peak-shaving and FM, and encourage the construction of distributed energy storage facilities in the user side and make them as demand side resources to participate in transactions in auxiliary services market. The advantage of the auxiliary services market to distributed energy storage is that the auxiliary services compensation mechanism provides economic incentives for the energy storage system, which plays role of subsidy and is more reasonable and sustainable than the subsidy because it is a kind of market-oriented incentive mechanism.

5. Research on the Development Strategy of Distributed Energy Storage Adapted to the Development of China 's Energy Internet

Opinions of the State Council on Actively Promoting the "Internet +" Action divides China's energy Internet development into two stages [15]. In order to enable the energy storage industry to participate in the construction of various stages of the energy Internet, support and promote the construction and development of China's energy Internet on the basis of development level of the energy storage industry. This section develops the integrating strategy of the storage energy and energy Internet. Combining the stage characteristics of energy Internet development and status and future trends of energy storage industry, energy storage to participate in energy Internet construction is divided into short-term stage and long-term stage, strategies are put forward in phases.

Short-term strategy corresponds to the first phase of the development of energy Internet, which is the stage of steady accumulation and development of energy storage. During this period, energy storage should focus on the technology, to cohesion and enhance the core competitiveness of the industry by controlling costs and clearing technical routes, in order to lay the foundation for deep participation in the energy Internet.

Medium and long-term strategy corresponds to the second phase of the development of energy Internet, which is the stage of rapid development of energy Internet. Energy storage will experience a boom in the early stages in this phase, and then may face bottlenecks in industrial development.

Therefore, at this stage, the energy storage should be adjusted and adapted to the needs of energy Internet, and realize the deep integration and coordinated development with energy Internet with the results of technology accumulation.

6. Conclusion

As a key link of multi-energy complement, distributed energy storage is the basis of energy Internet construction and development. This paper studies the orientation and application of distributed energy storage in energy Internet, and draws the following conclusions:

(1)The SWOT analysis provides the basis for the study of the function orientation of distributed energy storage in the energy Internet. The results show that, on one hand, the allocation of energy storage system can enhance the competitiveness of new energy in the electricity market, and distributed energy storage can have a broad development space under energy Internet background. On the other hand, the industry's immaturity, lack of experience in industry and government decision-making will also be a potential obstacle to future energy storage in the development of energy Internet. Industry's and government's decision-making lack of will be a potential obstacle to future development of energy storage in the energy Internet.

(2)Application modes of distributed energy storage in the energy Internet are diverse, mainly including:1) Distributed energy storage system can quickly respond to and coordinate new energy output, improve the VPP voltage environment and voltage quality.2) Distributed energy storage installed in the community or home, via the demand side response, can improve the user's electricity economy and energy using efficiency, which will be a useful and necessary add to the future power grid.3) Energy storage participating in auxiliary services, can increase the FM capacity of the grid and maintain the stable operation of the grid, which effectively Alleviating the new energy grid-connected and consumption.

(3)Cost-effectiveness and price response of distributed storage involve very complex factors. In the future, the market and price mechanism considering various types of energy storage are very important research directions. Deep studies are needed about the business mode and incentive mechanism of distributed energy storage resources to participate in large-scale new energy consumption and demand side optimization.

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