Analysis of the Application and Control of the Distributed Energy Storage System in Microgrid

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Abstract. Because of the intermittence and randomness of renewable energy and the continuous variability of load. By configuring a certain capacity of energy storage in microgrid, the active and reactive power throughput can be flexibly and quickly adjusted to smooth load fluctuations and reliability of power supply improvement. It can improve the power quality and keep the system stable. Therefore, the application potential of distributed energy storage system in microgrid and distribution system is huge. In terms of give full play to the performance advantages of energy storage through distribution system, it is necessary to study the core technologies of modular integration, topology, capacity design and control of energy storage through distribution system. The feasibility and value of energy storage through distribution system in power system engineering are demonstrated. Based on the analysis of relevant requirements, a energy storage through distribution system based on micro energy storage unit is proposed in this paper. This structure is very suitable for energy storage components to be connected to the micro-grid to achieve plug and play, high efficiency, high reliability and high flexibility of energy storage system applications.

1. Introduction
Due to the needs of remote areas and the existence of isolated energy islands, the concept of microgrid has been increasingly recognized by people, and related research results have become a focus of promoting sustainable economic and social development. However, power supply and demand are different in time and space. Especially in the microgrid system, because of the renewable energy intermittent and random nature and the continuous variability of the load. A certain capacity of energy storage is configured in the microgrid, and by flexibly and quickly adjusting the throughput of active/reactive power, it can smooth load fluctuations, reliability of power supply improvement, and improve power quality, and it can also maintain system stability.

At present, the microgrid with energy storage system is mainly based on centralized battery energy storage. The battery packs are connected in parallel and series to obtain higher voltage and capacity, and the power conversion system (PCS) is used as the interface to complete the power input and output. However, the centralized battery energy storage system has a series of problems such as battery voltage equalization, battery overcharge and overdischarge, poor battery compatibility, poor
system reliability, inability to plug and play, low space utilization, and difficulty in dynamic capacity adjustment. Some of these problems can be solved by the battery management system (BMS) in the centralized battery energy storage system, while some of them are difficult to solve based on the existing topology. Facing these problems, academic circles at home and abroad put forward the concept of Energy storage through distribution System (DESS). A typical energy storage through distribution system is composed of multiple energy storage battery units (ESU), each ESU integrates independent BMS and PCS, and can be distributed in space. The application potential of energy storage through distribution system in microgrid and even distribution network is huge. For make more better use of the performance advantages of energy storage through distribution systems, it is necessary to study core technologies such as modular integration technology, topological structure, capacity design and control of energy storage through distribution systems. Systematically demonstrate the feasibility and value of energy storage through distribution systems for engineering applications in power systems.

The BMS of the existing centralized energy storage system mainly manages the State of Charge (SoC) and voltage of the series battery pack. For the voltage imbalance of each battery pack, it is necessary to use a dedicated balancing circuit to solve it. At the same time, due to the differences in the capacity and performance of the battery cells, centralized charging and discharging can easily cause overcharge or overdischarge of the single cells, and make it difficult for battery packs with different output characteristics to be directly connected in series and parallel. These problems will increase the centralized energy storage system. The difficulty of design, deployment and maintenance. Therefore, this paper proposes a energy storage through distribution system based on micro-energy storage units based on the analysis of relevant requirements. This kind of structure is very suitable for the energy storage components to connect to the microgrid to realize plug-and-play, high-efficiency, high-reliability, and high-flexibility energy storage system applications. These works are of great significance for improving the security and stability of the power grid after the energy storage through distribution system is connected.

2. Related Research Progress and Trend Analysis
At present, the research hotspots of energy storage through distribution systems at home and abroad focus on the topology design of energy storage through distribution systems in different structures of microgrids, and the SoC balance control between the energy storage units of the energy storage through distribution system. The microgrid structures studied include AC microgrid, DC microgrid, and AC/DC hybrid microgrid. In the AC microgrid system, distributed power sources and energy storage through distribution devices are all accessed to the AC system bus by electric electronic devices. Through the control of the switch at the point of common coupling (PCC), the conversion between the microgrid grid-connected operation and the isolated operation mode can be realized. The distributed power sources, energy storage through distribution devices, loads, etc. in the DC microgrid system are all connected to the DC system bus by the electric electronic DC system bus by the electric electronic conversion device, and the DC system is then accessed to the AC power grid through the inverter device.

The overcharge or deep discharge of the ESU in the energy storage through distribution system will reduce the control range of the power distribution of the entire system, thereby affecting the capacity and life of the system. Therefore, studying the energy balance technology in the energy storage through distribution system is one of the keys to its practical application in the microgrid. It is also a problem faced by the current energy storage through distribution technology and a hot research topic at home and abroad. Xiaonan Lu et al. proposed a coordinated control algorithm for energy storage through distribution systems in DC microgrids [1,2]. They make the higher SoC ESU output more power by using the SoC-based droop control method, and the lower output of SoC ESU less energy, so as to achieve decentralized system-level SoC equalization, and the equalization speed can be controlled by droop SoC index to adjust. Nelson L. Diaz et al. proposed using fuzzy logic to dynamically adjust the virtual resistance in droop control of voltage based on the remaining energy of
each ESU [3,4]. But these control methods are not suitable for energy storage through distribution systems in AC microgrids.

From the perspective of the way the energy storage through distribution system is accessed to the grid and its control strategy, there are currently two main ways. One is to connect the energy storage system directly (or through a DC-DC converter) in parallel to the DC end of a renewable energy power electronic converter (DC/AC converter), and realize the energy storage system and renewable energy through this converter Energy conversion and control of energy and power grids. For example, a energy storage through distribution system based on DC bus signal proposed by John Schönberger and others at the University of Canterbury in New Zealand [5,6]. This DC convergence access method has the advantages of high reliability, low loss and easy control. The focus of its control research lies in the coordinated control between the renewable energy at the DC end, the energy storage system, and the load. However, it is susceptible to the limitation of the capacity of power electronic converters of renewable energy, which further affects the energy and power control capabilities of the energy storage system. The second is to connect the energy storage system directly to the grid via a power electronic converter (DC/AC or AC/DC+DC/DC), that is, connect it in parallel with the AC end of the renewable energy converter. For example, a highly reliable distributed power generation system based on energy storage proposed by H Kakigano, Osaka University, Japan. This DC convergence access method has the advantages of easy capacity expansion [7,8], convenient modular management and control, and is currently the most widely used access method.

At present, researches on microgrid systems based on energy storage through distribution are actively being carried out in China. Such as China Electric Power Research Institute, North China Electric Power University, and the Institute of Electrical Engineering of the Chinese Academy of Sciences have established a energy storage through distribution system model based on batteries and supercapacitors. The influence of energy storage through distribution on the operating characteristics of microgrid was studied, and a control strategy for using energy storage through distribution to optimize the operation of micro power sources and improve the power quality of microgrids was proposed.

3. Analysis of Key Points of Research
The study conforms to the development direction of power system service distributed generation access and distribution network of AC/DC hybrid, and closely integrates the needs of China's renewable energy power generation and grid connection. The research will improve the safety and stability of the existing power transmission and distribution network, promote the low-cost development and utilization of renewable energy with distributed, and promote the realization of the strategic goal of energy security in China.

3.1. System Research Key Point
Relevant research on the energy storage system structure and control strategy is a major breakthrough in the existing energy storage through distribution system technology. Research needs to coordinate control and control to solve the three major problems of low reliability of energy storage batteries, mixed use of batteries and energy storage utilization. This will provide a new idea for the research of power storage systems and energy storage conversion control technology in China, and has important scientific theoretical significance and academic value. This paper proposes to focus on the research, mainly for the energy exchange mechanism and coordinated control system structure of the energy storage through distribution system, to study the system topology and control strategy. The system analysis of key points of research is shown in figure 1.
3.1.1. Evaluation of Economics and Engineering Practicability of Energy storage through distribution Based on Micro Energy Storage Unit. Combining the actual needs of the project, systematically study the internal connection between the series-parallel mode of micro energy storage units, the number of strings, and the economics, reliability, and system life of the energy storage through distribution system. Use network theory and technology to study energy management technology of energy storage through distribution system.

The proposed energy storage through distribution system is compatible with energy storage components with different performances, and can meet the requirements of energy storage systems for different voltages, power levels and capacities through series and parallel combinations. In order to optimize the design of the structure and capacity of the system, the above-mentioned coupling factors need to be considered and balanced, which will be the focus of future research.

**Figure 1.** Analysis of key points
3.1.2. Capacity and Topology Optimization Design of Energy Storage through Distribution SYSTEM. Study the design method of micro energy storage unit and the combination of series and parallel with inconsistency of parameters. According to the energy storage grid-connected system requirements of different power and voltage levels and the battery performance parameter constraints, the optimization design method of the micro energy storage unit parameters is obtained. On this basis, the topology optimization design method and system capacity configuration principles of the energy storage through distribution system are proposed.

There are also inconsistencies in performance and parameters among the monomers of the same type of energy storage element. The energy storage through distribution system needs to be coordinated and controlled by BMS and PCS inside the micro energy storage unit, so that its external characteristics tend to be consistent, so as to ensure the performance and efficiency of the entire system. The individual performance energy storage components evaluation technology and the optimization control technology of micro energy storage units involved are also difficult points for future research.

3.1.3. Voltage Equalization Technology and Power Distribution Control Strategy. Research on the voltage equalization and charge-discharge curve control technology of the energy storage through distribution system to make the energy storage elements in each micro energy storage unit in the optimal working state, while ensuring the power output performance of the entire system. Research on the optimal distribution strategy of the power of the micro energy storage unit in the system under different load conditions and grid-connected/islanding working conditions in the microgrid.

At present, most of the energy storage systems in the microgrid and distribution network are centralized. How to use an energy storage through distribution system based on micro-energy storage units to flexibly, efficiently, and highly reliably ensure the quality of power supply in the microgrid, and systematically solve the topology involved in it, and then achieve control strategies and optimization design problems, these should be the main work in the future.

3.2. Technical Route
Related research will take a combination of extensive research, theoretical analysis, simulation verification and experimental platform verification. The system analysis of technical route is shown in figure 2.

![Figure 2. Analysis of technical route.](image-url)
First, conduct the topology research of the energy storage through distribution system to provide a theoretical basis for the next step of building a system simulation model and experimental platform.

Secondly, based on the existing domestic distributed power generation system simulation calculation platform, a energy storage through distribution system simulation calculation model based on series and parallel micro energy storage units is built.

Then, the institute puts forward the system topology, optimal design method and multi-objective control strategy in the system to provide technical support for building an experimental verification platform.

Finally, an experimental prototype will be built for functional verification, laying a foundation for project demonstration and large-scale promotion.

4. Conclusion

This paper proposes a energy storage through distribution system based on micro energy storage units. The smallest unit deployed in the energy storage through distribution system is obtained by integrating a single battery pack with a miniaturized BMS circuit and a PCS circuit. The high voltage and large capacity of the energy storage through distribution system can be obtained by connecting these micro energy storage units in series and parallel. Through this structure, not only can the corresponding voltage and power level requirements be met, but also because the PCS in the micro energy storage unit can stabilize the output voltage by itself, there is no need for a system-level BMS and equalization circuit. Since each battery pack can independently determine the charge and discharge curve according to its own parameters and output performance characteristics, it can well solve the problems of overcharge/overdischarge and system compatibility caused by inconsistencies.

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