Application of energy storage technology used in photovoltaic power generation system

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Abstract. Renewable energy needs the usage of energy storage technology to manufacture its energy utilization because of instability via environmental impact in generating electricity process. Therefore, energy storage technology plays an important role in the process of renewable utilization systems, many kinds of new energy technologies consider energy storage system as an part of their energy management as well as progress of corresponding technologies. This paper promotes the development of energy storage technology and application of two topological structures, expounds its the function in power system and comparison under various control methods.

1. Introduction
According to statistics of the European Union and the United States, by 2020, renewable energy accounts for more than 20% of the total energy consumption. Chinese government actively responds to the call for energy plans to achieve the target of 15% renewable energy utilization by 2020, which result in development of photovoltaic power generation continuously. Increasing capacity of photovoltaic power generation suggest that the role of energy storage technology gradually appears.

2. Research status of energy storage technology
Microgrid, composed of distributed grid in certain area, is used to provide heat, refrigeration and electric energy for regional load. Utilization of renewable energy generation including wind power and photovoltaic are affected by meteorological factors, leading to fluctuations in the output power during the generation process, forming an impact on the main grid and load. Scholars at home and abroad have designed energy storage devices to suppress power fluctuations in the process of renewable energy generation. Installation of the system also enhance the inertia of the micro-grid, improving anti-disturbance ability and strengthening the reliability and security of regional power grid. As depicted in Figure 2 that the development region and growth trend of MW level energy storage projects in several countries worldwide, showing that countries vigorously support energy storage projects and energy storage projects develop rapidly.

According to statistics of US Department of Energy Information Center, in recent years, more than 180 demonstration projects beyond MW-scale have been implemented in various countries, including nearly 100 electrochemical energy storage and more than 80 non-electrochemical energy storage.
Figure 1 (a) shows the status planning of energy storage demonstration project, Figure 1 (b) suggests that about 120 demonstration projects running, about 60 announced and 2 suspended.

(a)MW class energy storage system number (b)State diagram of large-scale energy storage system

**Figure 1.** Demonstration Projects and Status Division Diagram of Energy Storage System

(a)MW Class Energy Storage Regional Distribution Map (b)Growth Trend of Large-Scale Energy Storage System

**Figure 2.** Geographical Distribution of Energy Storage System above MW

3. **Function and operational mode of energy storage technology**

3.1. *Energy storage technology concept*

Energy storage refers to conversion of electrical energy into other energy through devices that store energy efficiently, converts the store energy into required form conveniently when needed. Therefore, control categories of the devices can be divided into two kinds: first kind is efficient and large-capacity energy storage methods and the second is fast and efficient energy conversion method. In traditional power network, energy transmission consists of power production, power transmission and power utilization is almost completely ‘rigid’, becoming ‘flexible’ with the help of energy storage technology, resulting in security, economical efficiency and flexibility of grid increasing [3] [4].

3.2. *Affect of energy storage technology in modern power system*

Energy storage technology plays an important role in the operation of power system as follows: Firstly, peak cutting and valley filling are used to improve the daily load rate of power system, increasing the utilization rate and operation efficiency of generating equipment. Secondly, emergency power supply improves reliability of system operation and power quality. Energy storage equipments act as emergency power supply to prevent power interruption resulting in big loss in several loads such as hospitals, fire fighting, communications, banks and so on. Third, combination of energy storage equipment and advanced power conversion equipment as primary frequency modulation achieve rapid control of the grid. Fourthly, as grid-connected renewable energy generation impact power grid easily,
photovoltaic power generation provide rapid switching through charging and discharging under combination of high-efficiency energy storage devices and wind power, supporting security and stability.

4. Operational mode of energy storage technology in photovoltaic power generation system

Main function of microgrid controller which provides micro-power supply ensuring the reliability of microgrid is power conversion. When connected to grid, power transmission process needs to be stable under control of the monitor, and power converter is intermediate channel for energy flow. Currently, there are two circuit topologies for power converters including single-stage as shown in Figure 3 and double-stage shown in Figure 4.

The two-stage converter in Figure 4 has a complex structure, including two bidirectional converters, which implement DC/DC and DC/AC functions respectively. Comparing single-stage with double-stager, it shows that double-stage converter achieve a wider range of voltage regulation and power conversion than single-stage converter and corresponding shortcoming of double-stage is its complex control method and larger operation loss.

![Figure 3. Structural Topology Diagram of Single-stage Converter](image-url)
Figure 4. Structural Topology Diagram of Two-stage Converter

5. Control methods of energy storage technology

5.1. Hysteresis Control
Hysteresis control, also known as ripple regulator control, maintains output voltage within the hysteresis width centered on internal reference voltage, is a closed-loop current tracking process based on current control, which is evolved from voltage source inverter. The characteristics of hysteresis control are simple control mode, fast dynamic response and current limiting capability. During operation process, feedback of current hysteresis control instantaneous comparator does not depend on the mathematical model and system parameters, so it does not need to approximate or simplify the system model improving system stability. However, control frequency of hysteresis controller is not fixed, which decline reliability and deteriorate spectrum of output voltage, adversing system performance effects.

5.2. Deadbeat control
Calculating PWM pulse width of next switching period according to inverter state equation and output feedback signal, deadbeat control is based on precise mathematical model of the controlled object. Delay effect in sampling and data calculation is considered in modulation process. In order to reduce utilization of input DC voltage, duty cycle of output pulse is limited by calculation and output of pacing.

5.3. Sliding mode control
Sliding mode control is to make output move up and down in high frequency and small amplitude with prescribed trajectory under certain conditions, which is discontinuous, a non-linear control method and also called synovial variable structure control. Characteristics are related to design plane under condition of sliding mode control, result in strong robustness, bad overall steady-state effect, difficult to select ideal sliding mode switching surface, and control effect is affected.

5.4. Repetitive control
Repetitive control is based on internal model control, which is to assume that the distortion of output voltage waveform in the previous cycle occurs repeatedly in next cycle. The controller determines
correction signal of system according to the error between specific parameter signal and output voltage feedback signal. Then correction signal is superimposed on the original control signal in next cycle to eliminate the periodic distortion signal of output voltage.

5.5. Fuzzy control
Fuzzy control method has strong robustness and adaptability with fuzzy module, which is helpful in system real-time performance improvement and output voltage waveform quality increasing. Accuracy of fuzzy control is mainly affected by membership function of fuzzy rules and variables.

5.6. Neural network control
Neural network control method simulates the intelligent activity of human brain nerve center system, which has the ability of non-linear mapping, applying to many fields of control, especially in nonlinear application.

6. Conclusion
This paper describes application and research status of energy storage technology and its role in power system through data analysis of recent years at home and abroad. The paper expounds two kinds of topological structures using in photovoltaic power generation system and makes a brief analysis about characteristics and differences between them. Finally, comparison and analysis of several modern control methods of energy storage technology are detailed.

Acknowledgements
Approval No. GJJ181053.

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