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Review of PEDF Air conditioning Systems for Flexible Energy Utilization

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Abstract

This paper reviews literature related to "photovoltaic, energy storage, direct current, flexible energy utilization" PEDF） systems. With the severe energy crisis and environmental pollution, the demand for clean and efficient energy has become more urgent. PEDF has become a powerful solution to energy problems because of its high efficiency, reliability, and flexibility. As air conditioning is a major energy-consuming part in buildings, its integration with PEDF has become a focus. This paper first introduces the research background and significance of PEDF air conditioning system, summarizes its working principle, and then introduces its flexible energy utilization strategy from the perspectives of "photovoltaic", "energy storage", and "direct current". Finally, this paper introduces practical projects of PEDF technology, and proposes related research suggestions and prospects.

Keywords: *PEDF; flexible energy utilization; direct current*

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I. INTRODUCTION

Energy is the foundation of national economic development. As early as the 1970s, the world oil crisis caused by war brought unprecedented attention to energy reserves and energy efficiency. Building energy consumption accounts for the majority of energy consumption, and air conditioning, as an indispensable part in modern buildings, has a significant impact on building energy consumption. According to statistics, air conditioning energy consumption accounts for about 40% of the total building energy consumption. In some high-temperature areas, the proportion of air conditioning energy consumption to total building energy consumption is even higher. In addition, air conditioning also faces problems such as high electricity consumption and large gap between peak and valley electricity consumption.

To solve these problems, researchers have begun to explore a new air conditioning technology called the "PEDF air conditioning system". PEDF refers to the integration of four technologies: photovoltaic, energy storage, direct current distribution, and flexible energy utilization. Based on a new type of renewable energy power system, it applies these four technologies to the air conditioning system, which can realize the energy reformation (increasing new energy proportion), energy system optimization, efficiency improvement, etc.

The PEDF air conditioning system adopts a flexible control strategy. "Flexible" refers to the fact that in the corresponding power grid of the system, the load's power consumption does not necessarily have to be equal to the power taken from the power grid, but can be automatically adjusted within a large range according to the supply-demand relationship between the load and the power grid. This control strategy can solve the problem of mismatch between power generation load and power consumption load on the user side.

PEDF is an important means to respond to the Chinese national carbon policies. It has received extensive attention and support from the governments and company. At the 9th meeting of the Central Finance and Economic Committee on March 15, 2021, it was first proposed to "construct a clean, low-carbon, safe and efficient energy system, control the total amount of fossil energy, focus on improving utilization efficiency, implement renewable energy substitution actions, deepen power system reformation, and build a new energy power system " The country strongly supports the development of renewable energy and promotes the transformation to a new type of power system.

According to research data from the team of Jiang Yi of Tsinghua University[1], renewable energy installed capacity in China will account for 80% of the total installed capacity in the future. With the continuous development and maturity of photovoltaic power generation and energy storage technologies, renewable energy such as solar energy has gradually become the main choice to replace traditional energy. By using photovoltaic power generation and energy storage technologies to achieve air conditioning cooling and heating functions, not only can energy utilization efficiency be improved, but also reducing the dependence on traditional energy, achieving sustainable development.

"Building energy conservation benefits the country and the people." This sentence is the motivation for countless energy-saving workers to work day and night. Through research and application of the "PEDF" air conditioning system, more new technologies for building energy conservation and emission reduction can be explored, promoting the development of the building energy conservation industry and continuous innovation.

1.1The basic working principles of PEDF air conditioning system

The PEDF system is equipped with four new technologies: Photovoltaic, storage, energy storage, direct current distribution and flexible energy utilization.

Typically, solar photovoltaic panels are installed on rooftops or other building surfaces to collect solar energy and convert it into electricity for use by the air conditioning system. However, the generation of photovoltaic power is affected by factors such as climate and location, in order to maintain the stability of the power system, photovoltaic power generation is often combined with energy storage device in reserve. Common energy storage devices include batteries such as lithium-ion batteries. Energy storage is important for energy storage and regulation. With the continuous development of technology, energy storage methods are no longer limited to energy storage batteries. New energy vehicles parked around buildings, HVAC systems, and building envelopes themselves can all be considered as energy storage methods.

The electricity generated by solar photovoltaic panels is usually direct current. Unlike traditional air conditioning systems that require alternating current to operate, the PEDF system can directly use the direct current generated by solar photovoltaic panels. The equipment in the system is connected to the direct current bus through a DC/DC (direct current) converter, establishing a direct current distribution system. This can avoid the energy loss caused by the DC-to-AC conversion (inverter) and improve the utilization efficiency. At the same time, using direct current technology can also achieve more accurate energy control and regulation, improving system stability and energy efficiency.

The ultimate goal of "photovoltaic, energy storage, direct current, flexible energy utilization" is "flexible energy utilization." That is, to transform buildings that are often only used as loads to consume energy in traditional energy systems into a renewable energy production, self-regulating and optimizing complex. The problem of mismatch between power generation and load consumption can be solved at the building end. Normally, near the building complex, there is a wind, solar, and electric power base. Every night, each PEDF building reports its total power consumption and power consumption curve for the next day to the control center of the photovoltaic, wind, and electric power base. Next, the control center will use weather forecasts to obtain the wind, solar, and electric power generation curve, and optimize the scheduling based on the power consumption curve reported by each building.

II. Flexible Utilization Strategy of PEDF System

2.1Flexible utilization strategy for Solar Energy

The flexible utilization strategy of solar energy is based on the fact that solar energy is a renewable energy source and can produce electricity during the day through sunlight irradiation. The core component for converting solar energy into electricity is the photovoltaic panel. In a PEDF system, the layout and selection of photovoltaic panels can be optimized to maximize the utilization of solar energy, making the system more flexible. For example, photovoltaic panels with trackers can be used to track the position of the sun and adjust the angle of the panel to achieve greater solar energy utilization efficiency. In addition, the output voltage and current of photovoltaic panels can be adjusted according to the intensity and angle of sunlight to adapt to different environmental conditions and load requirements.

When selecting the orientation and angle of photovoltaic panels, local sunlight and climate conditions must be considered. In the northern hemisphere, the best orientation for photovoltaic panels is generally facing south to obtain the most sunlight. On the contrary. in the southern hemisphere, it should face north. In addition, the tilt angle of the photovoltaic panel also needs to be adjusted according to the local latitude and season to achieve maximum solar energy utilization efficiency.

On top of that, the type and performance of the photovoltaic panel also need to be considered. Currently, there are mainly three types of photovoltaic panels on the market: monocrystalline silicon, polycrystalline silicon, and amorphous silicon. Monocrystalline silicon photovoltaic panels have the highest photoelectric conversion efficiency, but are also the most expensive. Polycrystalline silicon photovoltaic panels have a relatively higher cost-effectiveness ratio, while amorphous silicon photovoltaic panels are the cheapest, but have a relatively lower efficiency. In addition, the quality and stability of photovoltaic panels also need to be considered to ensure their long-term stable operation.

2.2 Flexible utilization strategy of energy storage technology.

Photovoltaic power generation is often combined with energy storage devices, which directly store electricity. Conventional energy storage devices include energy storage batteries such as lithium-ion batteries. These devices can be used directly as reserve for special situations such as extreme weather, or they can be used to store energy during low electricity price periods and release it during high electricity price periods, achieving the effect of "peak shaving and valley filling" in electricity prices. Ice storage and water storage systems are also used to achieve this effect based on the same principle. In the future, with the further reduction of battery costs and the widening of peak and valley electricity prices, the economic benefits of building energy storage will become increasingly significant.

In addition, under the circumstance of ensuring the operation of building equipment and the comfort of people, flexible energy utilization can also be achieved by controlling and adjusting the building equipment itself.

In the PEDF air conditioning system, the air conditioning system itself is a typical adjustable load. During the summer peak period, air conditioning loads account for 30% to 40% of peak loads on the power grid and have been showing an upward trend in recent years. In terms of energy conservation, the building envelope itself has a certain capacity for heat storage and cold storage, influencing the indoor temperature and humidity by radiation heat transfer. To a certain extent, air conditioned rooms can be regarded as an energy storage battery, and temporarily closing or changing the frequency of the variable frequency air conditioning system will not affect the comfort of building users, providing the chance for adjusting air conditioning loads and achieving the effect of flexible energy utilization.

Moreover, the water heater is also a typical energy load with high instantaneous power and high energy consumption, as well as a heat storage capacity similar to that of traditional energy storage devices. Without affecting comfort of users, the water heater can be regarded as a virtual energy storage device and participate in demand-side response. The water heater can be adjusted according to time to reduce the overall load peak and achieve energy conservation. Specifically, the set temperature of the water heater can be reduced during the power grid peak load period for virtual energy storage discharge, while it can be raised before the power grid peak load period to achieve virtual energy storage charging and smoothing of the overall load valley effect. This flexible utilization strategy can effectively reduce the energy consumption of the entire building and improve the building's energy utilization efficiency.

In summary, through the implementation of the above flexible energy utilization strategies, building equipment can more efficiently use and store energy to achieve energy balance and conservation, while also reducing reliance on the power grid and enhancing the building's sustainability.

2.3 Direct current technology

Direct Current distribution is a technology method for achieving flexible energy utilization. DC distribution systems enable flexible utilization of solar energy, as they can directly transmit the DC power generated by photovoltaic panels to energy storage systems, thereby avoiding losses due to AC conversion. Additionally, DC distribution systems can adjust current and voltage based on load demand and the output of photovoltaic panels, maximizing the use of solar energy and ensuring system flexibility and reliability. With the development of DC power sources and loads, it may become more reasonable for buildings to adopt DC distribution systems. Common DC power sources such as distributed photovoltaics and energy storage batteries, combined with the gradual replacement of traditional lighting fixtures with LED lights and increasing demand for variable-frequency air conditioners, water pumps, and digital devices, make it feasible to eliminate the AC/DC conversion between DC devices and the distribution network. This reduces losses due to AC/DC conversion, improves energy utilization efficiency, and releases restrictions on voltage and frequency, leading to advantages such as improved energy efficiency, reliability, lower costs for inverters, and simpler equipment off-grid and power balance control.

With the rapid development of building photovoltaics, building energy storage, terminal equipment DC conversion, and power electronics technology, the advantages of building DC distribution are gradually becoming apparent. Developing low-voltage DC distribution is an exploration of the future form of building distribution systems, aiming to meet new demands such as efficient utilization of building photovoltaics and energy storage, flexible load aggregation control, high-quality and reliable power supply. It requires designing new architectures, defining new interfaces, and proposing new system solutions.

III. Practical projects of PEDF system

Shanghai's first PEDF building, the Zhonghuan Taopu Science and Technology City project in Putuo district, is also Shanghai's first low-carbon demonstration project that integrates PEDF, near-zero energy consumption and intelligent construction.

The project is located in the core area of the Taopu Smart Innovation City in Putuo district, Shanghai, and is a benchmark site for comprehensive development that includes residential, commercial, sports center, and kindergarten etc.

Taking Building A8 as an example, over 300 square meters of polycrystalline silicon photovoltaic power generation equipment is installed on the roof. The energy produced is stored in lithium battery energy storage equipment and is supplied to the building's lighting, electric vehicle charging stations, and DC appliances through a flexible power management system. The photovoltaic system generates 68,000 kilowatt-hours of electricity per year, saves about 75,000 yuan in electricity bills per year, and reduces carbon emissions by 28.68 tons!

In terms of building energy efficiency indicators, both the commercial and affordable housing in this project have set high standards for near-zero energy consumption. More stringent requirements are implemented in the thermal insulation measures of the building envelope, air tightness design, and thermal bridge node control. The air conditioning heating, fresh air, domestic hot water, lighting, and photovoltaic systems all pursue higher levels of energy conservation and emission reduction.

By implementing various near-zero energy consumption technologies, this project will significantly reduce the building's electricity and gas consumption, thereby reducing carbon emissions. The project is expected to reduce CO2 emissions by 893.49 tons per year. The pilot near-zero energy consumption in this project can explore more energy-saving and low-carbon new technologies and materials, while ensuring comfortable and healthy living environment for residents and saving daily energy costs, which is in line with the current promotion of green development.

Figure 1 PEDF building demonstration

IV. CONCLUSION

With the growth of energy demand and the increasingly serious environmental issues, exploring new ways and technologies for energy utilization has become an important topic in the global energy field. Light-storage-direct-flexible air conditioning is an emerging energy utilization technology, which fully utilizes technologies such as solar photovoltaic power generation, battery energy storage, DC distribution, and flexible load control, achieving efficient energy utilization and optimized management. It also contributes to building energy conservation and emission reduction, as well as green and low-carbon development. In the future, with the continuous improvement of technology and the continuous promotion of application, light-storage-direct-flexible air conditioning will be applied in a wider range, bringing more convenient, comfortable, and sustainable living environment for people.

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