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Current Status and Application Analysis of Solar Photothermal and Optoelectronic Technology

Hanyu Zhao *

HD Ningbo School, Ningbo, Zhejiang, 315101, China
*** Corresponding author Email:** spikezhao2887@outlook.com

Abstract: With the development of society, energy issues have been increasingly valued. Solar energy, as an emerging energy source, has received widespread attention. This article conducts in-depth research on the application of solar technology in different fields. Firstly, the basic principles of solar photothermal technology and solar photothermal technology are analyzed. Secondly, the applications of photothermal and photovoltaic technology in different fields are introduced. Finally, the development status of solar photothermal and photovoltaic technology is discussed.

Keywords: Solar Energy; Photovoltaic; Photothermal; Power Generation Technology.

1. Introduction

Since entering modern society, people's living standards have continuously improved, and the accompanying problems are that human demand for energy is higher than ever before, and the shortcomings of energy shortages have gradually expanded, especially in traditional fossil fuels such as coal, oil, and natural gas. As a new renewable energy source, solar energy is currently one of the important choices for humans to cope with energy shortages, and has advantages that are different from traditional fossil fuels such as environmental protection, cleanliness, and durability. It has a great development prospect that is favored by various countries.

Solar energy resources have the following advantages and universality: most areas of the Earth can be refracted by sunlight, which is very extensive and does not require extraction and transportation; Cleanliness: Unlike fossil fuels, the use of solar energy resources can effectively control the impact on the environment and is a clean energy source; Abundance: The solar Radiant energy reaching the earth's surface every year is about 130 trillion tons of standard coal, which is 10000 times the total energy consumed by the world every year. Solar energy is almost infinite to humans. At the same time, solar energy resources also have several drawbacks, including low efficiency. Currently, the devices used to utilize solar energy resources have low efficiency, high costs, and overall economic competitiveness that cannot compete with conventional energy; Discontinuity: Terrain, time, and air can all have an impact on the collection of solar energy resources; Dispersion: the unit energy density varies greatly between different geographical locations, and most of them are low.

The application of solar energy technology in the utilization of solar energy resources in human life mainly includes several categories: photothermal conversion, photoelectric conversion, photobiological utilization, and photochemistry. Photothermal conversion and optoelectronic conversion, as relatively mature technologies, have already achieved multiple research results.

2. Application of Photovoltaic Power Generation Technology

The so-called "photovoltaic power generation" is a power generation technology that uses solar cells to convert solar energy into electrical energy based on the principle of photovoltaic effect. Whether used independently or connected to the grid for power generation, its Mnemonic major system is composed of solar panels, controllers, inverters and other electronic components. Therefore, photovoltaic power generation equipment has the advantages of refining, long-term use, and faster and easier installation. In theory, photovoltaic power generation technology can be used in various places, and it is ubiquitous[1].

2.1. Solar Cell

Solar cells are currently one of the more mature application points of photovoltaic power generation technology. The key to the research of photovoltaic power generation technology lies in the conversion efficiency of solar cells. Improving conversion efficiency means the utilization of more electricity. Professor Green divides the development of solar cells into three generations. The first generation is represented by monocrystalline silicon and polycrystalline silicon, which are mainly made of crystalline silicon and are currently the most mature and widely used solar cells. Among them, monocrystalline silicon solar cells are the most stable and mature type of crystalline silicon solar cells, but they have high requirements for manufacturing materials and complex manufacturing processes. Although polycrystalline silicon solar cells have lower conversion efficiency than monocrystalline silicon solar cells, they have the advantages of low requirements for manufacturing materials and low manufacturing costs. The second generation is thin film solar cells represented by arsenic arsenide (GaAs), Cadmium telluride (CdTe) and copper indium gallium Selenium compounds (CIGS). Therefore, this type of solar cell has a low demand for materials and has a significant cost advantage over the first generation of solar cells. Among them, gallium arsenide thin film solar cells have high conversion efficiency and are resistant to high temperatures and radiation, but due to their high manufacturing cost, they are difficult to be

applied in the civilian field. Cadmium telluride also has high conversion efficiency and the advantages of flexibility and transparency, but both Cd and as are toxic elements, which hinders the promotion of Cadmium telluride thin film solar cells to a certain extent. Copper indium gallium selenium thin film solar cells have the advantages of high efficiency and long service life, but their complex manufacturing process and demand for various materials also hinder their promotion to some extent. The third-generation solar cells are a new type of solar cell based on environmental protection, high efficiency, and nanotechnology, mainly including fuel sensitized solar cells (DSSCs) and calcium titanium[2]. As shown in the figure 2, there has been a significant increase in the production of solar cells in China from 2015 to 2022.

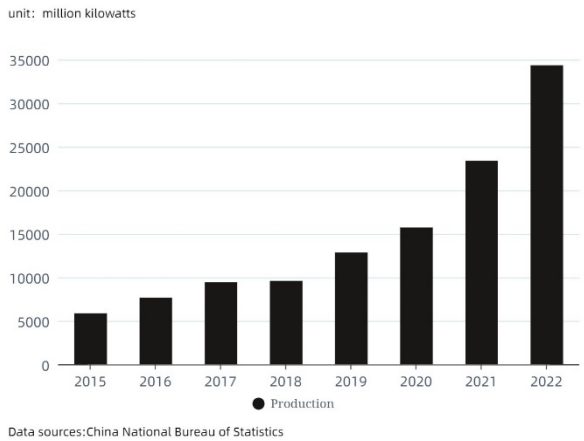


Figure 1. Statistical Chart of National Solar Cell Production from 2015 to 2022

2.2. Photovoltaic Power Generation System

The photovoltaic power generation system is composed of a variety of components, mainly including stand-alone photovoltaic system and grid connected photovoltaic system. The independent photovoltaic power generation system is mainly composed of Photovoltaic system, charge discharge controller, battery, load and other components. The Photovoltaic system is responsible for converting light into electricity; The charge and discharge controller is responsible for converting the electric energy transmitted from the Photovoltaic system into suitable voltage, charging the battery and supplying power to the load respectively, and the inverter equipped with the power generation system converts DC power into AC power. Generally speaking, the system converts sunlight into electrical energy during the day, stores it through a charger and battery, and releases the stored energy from the battery for appropriate use at night through a discharge device. Although the reliability of its power supply is greatly affected by factors such as meteorological environment and load, and the stability of its power supply is relatively poor, for residents located in remote areas, they often do not have the conditions to connect to the public power grid, and the electrical equipment is mostly of low power level. Therefore, independent photovoltaic power generation systems have become a safe and reliable local power supply method. Compared with independent photovoltaic power generation system, grid connected photovoltaic power generation system is relatively simple in structure and composition. This type of power generation system consists of Photovoltaic system, Grid-tie inverter, boost equipment and other parts. This system can directly transmit the obtained electrical energy to the power generation system of the urban power grid through grid connected equipment, directly supplying power to the urban power grid[3]. In the first quarter of 2023, China added 33.66 million kilowatts of photovoltaic grid connection nationwide, a year-on-year increase of 154.8%. Among them, centralized photovoltaic power generation accounts for 15.53 million kilowatts, while distributed photovoltaic power generation accounts for 18.13 million kilowatts. By the end of the first quarter of 2023, China's installed capacity of photovoltaic power generation had reached 425 million kilowatts, with 249 million kilowatts of centralized photovoltaic power generation and 176 million kilowatts of distributed photovoltaic power generation.

2.3. BIPV

BIPV (Building Integrated Photovoltaic) is an application of photovoltaic power generation technology in the construction field. If electricity generating materials are used as a building material, receiving sunlight during the day to absorb solar energy and convert it into electrical energy storage, meeting some of the building's electricity energy needs. Compared to photovoltaic systems (BAPV, building attached photovoltaic) installed directly outside the building, BIPV can not only provide a portion of the building's electricity by integrating photovoltaic power generation components with the building, At the same time, as a building material, it also has corresponding structures and functions, which can save some of the space originally used to provide power. Under the material usage standards of the construction industry, photovoltaic battery packs can be used as building materials, such as copper indium gallium selenium thin film batteries, which can be applied to different environments depending on their substrate[4]. Even though BIPV has multiple advantages, currently using photovoltaic materials to replace traditional building materials as an important external part of buildings still has significant impacts and risks.

3. Application of Photothermal Technology

3.1. Solar Heating System

The solar heating system uses solar energy as the main source of heat for the heating system. It absorbs and converts solar energy into heat energy that can be effectively utilized through solar collectors, in order to supply the residents' demand for heat energy during winter and the demand for other heat energy systems throughout the year [5]. Solar heating systems can mainly be divided into two types: active solar heating and passive solar heating. The active solar heating system is mainly composed of a combination of solar energy collection system, heat storage system, end heating system, automatic control system, heat exchange system, and other energy assisted heating systems. The passive solar heating method, on the other hand, is relatively independent of other external devices. It stores and distributes the received solar radiation by designing the orientation of the building, arranging the surrounding environment and internal space, selecting a reasonable external building shape, and selecting the materials used in the building. Because passive solar heating does not rely on external equipment, it has poor heating stability compared to active solar heating. Although the structure of active solar heating systems is more complex and costly, their thermal energy supply is more stable. With the development of the times, various shortcomings that

hinder the development of active solar heating systems will be gradually improved, and active solar systems will eventually be accepted by the public.

3.2. Solar Thermal Power Generation

Solar thermal power plants have the ability to generate electricity continuously and can be stored or deployed. Currently, there are three main types of solar thermal power plants: tower type, slot type, and disc type, with the main difference being the focusing method. The other working principles and system components are relatively similar. The tower type solar thermal system mainly uses a heliostat to concentrate sunlight on a receiver placed in the center of the spotlight, converting the collected solar radiation into thermal energy. Then, through the steam turbine driven by the thermal cycle, the thermal energy is converted into usable electrical energy. Indirect irradiation solar receiver, also known as exposed solar receiver, is characterized by the fact that the heat transfer process from the receiver to the heat carrying working medium does not occur on the solar irradiation surface. During operation, the focused incident solar energy first heats the heating surface, which then transfers heat to the working medium on the other side through the wall. Slot solar photothermal power generation system, also known as a dispersed system, is generally composed of a heat storage device. Composed of a condensing device, a heat engine device, and an auxiliary heat source. By using a trough concentrator to concentrate sunlight into a single line and installing a collector on the line, the solar radiation gathered into a linear shape is absorbed and converted into thermal energy. The disc solar thermal system utilizes a rotating disc shaped reflector to gather sunlight at the focal point of the collector and convert it into thermal energy, which is then driven by a steam turbine to generate electricity and achieve photothermal power generation. The main solar thermal power generation systems that have been built in major countries around the world are mainly through solar thermal power generation systems, while in China, the development of this area started relatively late with tower solar power generation systems as the main focus.

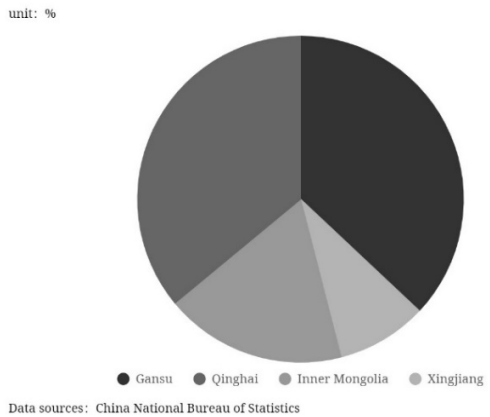


Figure 2. Regional distribution of solar thermal generators in China in 2021

According to regional distribution, as the figure 2 the 9 solar thermal power generation projects that have been grid connected or trial run in China are mainly concentrated in the northwest region, with Gansu, Qinghai, Inner Mongolia, and Xinjiang accounting for 37%, 36%, 18%, and 9% respectively.

4. Present State and Perspectives

Due to the origin of solar photovoltaic power generation technology in Western countries, China started relatively late. However, in recent years, with the unremitting efforts of Chinese scholars, China has also achieved many achievements in the field of solar photovoltaic power generation. In the civilian field, with the improvement of residents' living standards, the demand for electric energy is also increasing. Installing solar panels in areas with sufficient solar energy can meet some of the needs and alleviate power supply pressure. At the same time, solar thermal utilization, as another form of solar energy utilization, is making an increasing contribution in providing thermal energy, regulating room temperature, and alleviating some power supply needs[5]. Although solar energy is a green and pollution-free clean energy source, its collection is easily affected by the natural environment, and the conversion efficiency of solar energy is currently low. Therefore, there are still many problems to be solved and improved for the utilization of solar energy.

5. Conclusion

Solar thermal and photovoltaic technologies have been widely applied in many fields, some of which are close to popularization. With the development of the times, the advantages of solar energy in various aspects will continue to emerge, and its potential will continue to be explored. Solar energy application technology will continue to be improved in research, and efforts should be made in various fields to ensure that the advantages of solar energy can be utilized as much as possible.

References

[1] Groesbeck, J. G., & Pearce, J. M. (2018). Coal with carbon capture and sequestration is not as land use efficient as solar photovoltaic technology for climate neutral electricity production. Scientific reports, 8(1), 13476.

[2] Dambhare, M. V., Butey, B., & Moharil, S. V. (2021). Solar photovoltaic technology: A review of different types of solar cells and its future trends. In Journal of Physics: Conference Series 1913(1), 012-053.

[3] Li, Q. (2021,). Research on development problems and countermeasures of distributed photovoltaic power generation projects. In IOP Conference Series: Earth and Environmental Science 651(2). 022-089.

[4] Fouad, M. M., Shihata, L. A., & Morgan, E. I. (2017). An integrated review of factors influencing the perfomance of photovoltaic panels. Renewable and Sustainable Energy Reviews, 80, 1499-1511.

[5] Jackson, M. M., Lewis, J. I., & Zhang, X. (2021). A green expansion: China's role in the global deployment and transfer of solar photovoltaic technology. Energy for Sustainable Development, 60, 90-101.