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Solar Thermal Power Generation Technology Development

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Abstract: Fossil energy is running out faster and faster these days, and pollution in the environment is becoming a major issue. There are many opportunities for the growth of clean energy, particularly solar energy, under the "two-carbon" strategy. The production of solar electricity offers the benefits of plentiful resources as well as clean and environmental protection, which is becoming a crucial aspect of global energy consumption. In order to better understand the development of solar thermal power generation technology, this paper compares four different types of solar thermal power generation technology: trough thermal power generation technology, tower thermal power generation technology, dish thermal power generation technology, and linear Fresnel thermal power generation technology. It also evaluates the benefits and drawbacks of each technology and provides an overview of the advancements made in solar thermal power generation both in China and internationally. An introduction is given to the need and state of development for solar thermal power generating. The future and development prospects of solar thermal power generation technology are finally discussed.

Keywords: System type, solar energy, renewable energy, solar thermal power generation.

1. Introduction

The depletion of fossil fuels has accelerated in recent years, while environmental contamination has increased. Reducing reliance on non-renewable energy sources and lessening the effects of global climate change require achieving a robust and sustainable development of renewable energy sources. Biomass, wind, water, geothermal, and solar energy—the latter of which has tremendous development potential—are the main sources of renewable energy. Their advantages include zero pollution, zero secondary waste, and renewable energy. The conversion of solar energy into electricity is required for the convenience of energy transportation and consumption.

The two primary categories of solar energy use at the moment are solar thermal power generation and solar photovoltaic power generation. The concentrator in solar thermal power generation gathers light energy, which is then used to heat a heat transfer medium—such as molten salt or thermal oil—in the heat collector. After that, the heat transfer medium heats the water to a high degree and produces high pressure steam via a heat exchange mechanism. The generator generates energy through the use of steam to power the turbine.[1] The comprehensive structure, cheap cost, and high-power generation efficiency of solar thermal power generation technique make it superior to conventional

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power production technology. The trough, tower, dish, and linear Fresnel kinds of solar thermal power generation are the most widely used varieties.[2]

The fundamental idea and structure of the solar thermal power generation system are the primary subjects of this article. the benefits and drawbacks of various photothermal power generating methods as well as the development and future of the technology.

2. The basic principle of photothermal power generation technology

The heat collection system, steam generator system, heat storage and exchange system, and power generation system make up the solar thermal power generation system.[3] In order to achieve the conversion of light energy into heat energy, the heat collecting system employs the control device to make sure that the mirror field optical device tracks the sun. After that, it gathers light energy and creates a high energy flux density. In order to generate high-temperature steam that powers the turbine, the working medium in the steam generator is heat exchanged. Systems for heat exchange and storage typically use chemical reaction, sensible, and latent heat storage to store solar energy. The power generation system produces electricity by converting thermal energy.

3. Types and advantages and disadvantages of photothermal power generation technology

A technique known as photothermal power generation through the conversion process of light-heat-work. Photothermal power generating technology can be further classified as solar gas power generation, solar cell power generation, solar ultrasonic power generation, solar semiconductor thermal power generation, and concentrating photothermal power generation (CSP) based on various concepts. The four most widely used technologies for concentrated solar photothermal power generation are trough solar thermal power generation, tower solar thermal power generation, dish solar thermal power generation, and linear Fresnel solar thermal power generation. Tower type and dish type are point focused, whereas trough type and linear Fresnel type are line focused.

3.1. Trough solar thermal power generation

As seen in Figure 1 [4], the condenser, endothermic tube, and collector constitute the major components of the trough heat collection system. Trough solar power generation uses the trough paraboloid mirror, which focuses the sunlight on the vacuum tube collector to heat the heat transfer working medium. Heat from the heat exchanger's power cycle working medium encourages the thermal engine to expand and work more, driving the generator to produce electricity. The main working medium is heating conduction oil and molten salt.

Trough photothermal power generation has some advantages of mature technology, high reliability and simple optical control: The collector rotates with the condenser, and the tracking cost is reduced. However, its light concentration is relatively low, generally 70-100 times, the heat collection system is complex, and the pipeline is long. The system has a poor power and efficiency level and a high rate of heat loss.[5]

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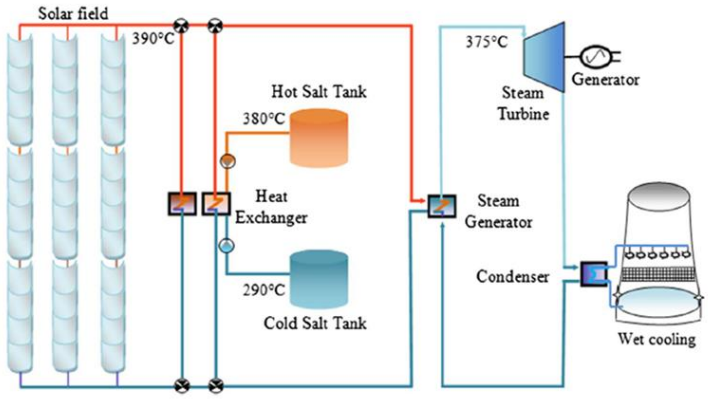

Figure 1: Schematic diagram of trough type photothermal power generation system[4].

3.2. Tower solar thermal power generation

The heat absorber, power generation system, and heliostat make up the tower thermal system's primary components. Each dual-axis tracking heliostat can precisely concentrate and reflect sunlight on the absorber at the top of a tall tower, converting solar light energy into heat energy. These heliostats are dispersed throughout a vast region. Through high temperature heat transfer and thermal storage heat transfer, the heating power cycle works medium and drives the thermal engine expansion to do work, finally driving the generator to generate electricity.

The principal benefits of tower-type photothermal power generation are: low heat loss and high photoelectric conversion efficiency; Heliostat two-axis solar light tracking and fixed heat absorber; high concentration multiple, typically 200–1000 times, and operating temperature up to 1000℃.[6] But the tower solar thermal power station's heliostat number is high, and the control system is intricate, adding to the cost and difficulties of the technology.

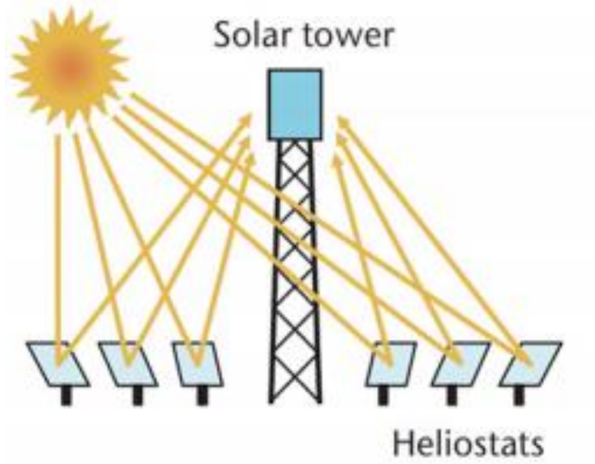

Figure 2: Schematic diagram of tower type photothermal power generation system[7].

3.3. Dish solar thermal power generation

A revolving paraboloid mirror is used in the dish solar thermal power generation system to collect incident sunlight at the focus. A solar receiver is then positioned at the focus to collect heat energy at a higher temperature, which heats the working medium and powers the generator that is set to produce electricity. Alternatively, to create energy, install a solar stirling power generation gadget right at the focal point.

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The disk-condenser, Stirling machine, and transmission system are the three primary parts of the Disk-Stirling power generation system. It operates at 800°C[8] and has a high concentrating ratio of over 3000 times[9]. The highest power generation efficiency, up to 31.25%; And it can be combined with other power generation methods and other advantages, while its high cost, low reliability of Stirling engine, and difficult to integrate heat storage system.

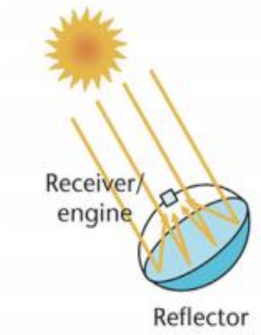

Figure 3: Schematic diagram of dish photothermal power generation system[7].

3.4. Linear Fresnel solar thermal power generation

Linear Fresnel solar thermal power generation composes a Fresnel reflector, endothermic tube and transmission system. It is composed of a number of flat single-axis rotating reflectors. A rectangular mirror automatically tracks the sun, reflecting sunlight to the upper secondary condenser, and then is gathered to a long tubular heat absorption tube, and heated water to produce about 270℃ steams directly driving the rear turbine engine.

Linear Fresnel power generation systems have the advantages of simple structure and high operating efficiency; The construction cost and the technical difficulty are low. However, it has low light concentration and low solar energy conversion efficiency.[10]

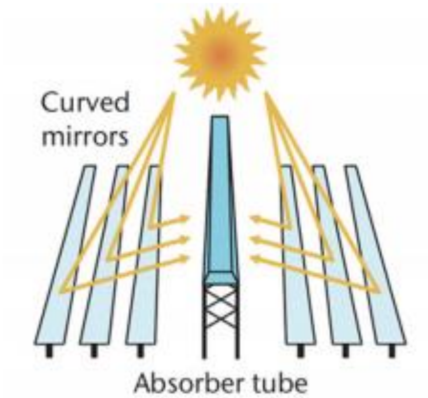

Figure 4: Schematic diagram of linear Fresnel type photothermal power generation system[7].

4. Development status

4.1. Current situation of foreign development

Foreign research on solar thermal power generation is earlier, there has been a study on solar thermal power generation since the 1880s.

In 1985, the world's first commercially operated trough power station was built in the United States (SEGS). The power station has a total installed capacity of about 350MW and is equipped with nine trough power generation systems with an annual generating capacity of up to 800GW·h. The SEGS power station is crucial to the advancement of CSP technology. The world's largest single-unit capacity of 160MW trough solar thermal power station was built in Morocco in 2016.[11]

4.2. Domestic development status

Compared with foreign solar thermal power generation technology, China's solar thermal power generation technology research was late until the 1970s, but progress was faster.

China's first 70KW tower solar thermal power station was built in Nanjing in 2005. The condenser has an area of about 30m2, an operating temperature was about 400℃, and a peak thermal output power of 100KW. It has the advantages of high automatic tracking accuracy and high heat flux. Qinghai Central Control Delingha 50MW tower solar thermal power station was built in Qinghai in 2013, with a capacity of 50MW and a 7-hour molten salt energy storage system. It is one of China's first solar thermal power generation demonstration projects. The 200KW trough plus linear Fresnel solar concentrated power generation test system has been successfully built in Lanzhou, with an active power of more than 150KW, which is of great significance for the medium and high temperature solar energy collection energy supply and photothermal power generation in China.

The channel CSP solar thermal power station currently makes up the majority of all solar thermal power station worldwide. The most promising CSP technology for use in commercial operations is thought to be tower CSP technology.[12]

5. Challenges and prospects

China's solar thermal power generation is in its infancy, its power stations' basic technologies and equipment are imported, and their costs are excessive—roughly five times higher than those of photovoltaic, coal, and wind power plants. Finding an effective heat storage media is essential to raising the photoelectric conversion efficiency of solar thermal power generation, which is currently low. To achieve China's aim of energy transformation, solar thermal power generation development is crucial.

In our next development, we should be mindful of the following:

- (1) High-temperature heat collection and storage technology research is essential to the advancement of solar thermal power generation to big capacities and high operating parameters.
- (2) To study the influence of different natural environments on the heat collection of photothermal power generation, improve the prediction accuracy of photothermal power generation power, and provide reliable decision-making basis for the transmission and storage system of the power station, so as to achieve efficient operation and improve output.
- (3) In the future, relevant standards such as system stability, dynamic performance and multi-energy complementary integrated operation should be formulated in combination with the actual development status of solar thermal power generation in China.
- (4) Improving the economic evaluation of solar thermal power generation is the key to enhancing its competitiveness.

6. Conclusion

The energy crisis is becoming increasingly serious, and the pollution problem is urgently solved, which will promote research into renewable energy. Solar energy is the ideal energy source to meet the growing demand for electricity, and it will continue to innovate and utilize in the future. This paper introduces the basic principle of photothermal power generation technology and four types of photothermal power generation technology. Photothermal power generation collects light energy

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through the condenser, heats the heat transfer medium such as thermal oil or molten salt in the heat collection device, and heats the heat transfer medium through the heat exchange device to heat water to high temperature and high-pressure steam. The steam turbine drives the generator to generate electricity. There are four common types of solar thermal power generation: trough type, tower type, dish type and linear Fresnel type.

An overview is given of the state of research and development for solar thermal power generation technologies both domestically and internationally. In the 1880s, other nations started to take an interest in the advancement of solar technology and constructed the first trough power station for commercial use. Though it is late in coming, indigenous solar thermal power generation technology is advancing more quickly. Prospects are presented together with a discussion of the issues and difficulties that currently exist.

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