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SOLAR THERMAL POWER GENERATION TECHNOLOGY RESEARCH

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ABSTRACT

The central receiver concept for power generation by solar energy is receiving attention since it is expected to increase the overall efficiency of a solar-based power plant. Recent research on the subject led to the construction of a 10 Megawatts of electricity (MWe) pilot plant in Barstow, California. The receiver system of that plant consists of 24 panels of 13.72m. (45 ft) height and 0.89m. (35 in.) width composed of 12.7mm. (½ in.) diameter tubes of Incoloy 800. Water moving upward through the panels is converted to steam by sunlight reflected from the mirrors of a heliostat field. The expansion of steam in a turbine and its eventual return to the receiver downstream from a condenser complete the thermodynamic cycle. A major disadvantage of this central receiver is the need to transfer heat to the fluid through the walls of the tubes of the panels, which results in loss of energy and reduced overall efficiency. An improvement results when the fluid is heated directly without the interference of a tube wall. This is accomplished with an optical cavity receiver provided with a well-insulated interior inclined surface over which an absorbing liquid flows by gravity and is heated with the sunlight reflected from the heliostats. It is estimated that temperatures of over 1000°C are achievable. This paper summarizes current research activity in the area.

1. INTRODUCTION

Solar radiation is the cleanest, most abundant form of energy supply on earth. Three days of solar energy is equivalent to the world's fossil fuel reserves, which are dwindling as their usage continues. Yet, solar energy has not been accepted as a major source of energy.

Availability of inexpensive fossil fuels and the fact that solar radiation is distributed unevenly around the globe with the most energy arriving at remote desert areas discouraged research in solar energy conversion technology. The energy crisis of the seventies, however, was instrumental in changing this condition. As a result a solar energy industry was established, and a fair amount of research and development work was initiated. One such area of research work is thermal power generation, which is the topic of this paper

2. SOLAR POWER GENERATION TECHNOLOGY

Solar technologies convert sunlight into electrical energy either through photovoltaic (PV) panels or through mirrors that concentrate solar radiation. This energy can be used to generate electricity or be stored in batteries or thermal storage. There are two main types of solar energy technologies—photovoltaics (PV) and concentrating solar-thermal power (CSP).

2.1 Photovoltaics Basics: You're likely most familiar with PV, which is utilized in solar panels. When the sun shines onto a solar panel, energy from the sunlight is absorbed by the PV cells in the panel. This energy creates electrical charges that move in response to an internal electrical field in the cell, causing electricity to flow.

2.2 Concentrating Solar-Thermal Power Basics: Concentrating solar-thermal power (CSP) systems use mirrors to reflect and concentrate sunlight onto receivers that collect solar energy and convert it to heat, which can then be used to produce electricity or stored for later use. It is used primarily in very large power plants.

3. TECHNICAL ANALYSIS OF SOLAR THERMAL POWER GENERATION

Since the oil crisis in the early 1970s, the major developed countries in the world, such as the United States, Spain, Germany, Switzerland, France, Italy and Japan, have taken solar thermal power generation technology as the focus of national research and development, gradually started to develop solar thermal power generation on a large scale, and established a large number of experimental power stations. In the last 20 years, there have been about 20 solar thermal power stations (over 500 kW) built around the world, and some of them have been put into commercial operation [7]. By the end of 2018, the installed capacity of global solar thermal power generation has reached 6.The installed capacity of 3GW in the United States, Spain and other countries has been successfully put into commercial operation. Although China's research on photovoltaic power generation is relatively late, through in-depth research, tests and verifcation, China's own photovoltaic power generation technology has developed rapidly, and the installed capacity of photovoltaic power generation in China has reached 79000 kW. According to the diferent power generation principles, Solar-thermal power generation includes concentrated Solar-thermal power generation, solar semiconductor temperature difference power generation, solar chimney power generation, solar pool power generation and solar thermal acoustic power generation. Among them, concentrated Solar-thermal power generation is the most commercial use of the most promising technology. Among them, concentrated Solar-thermal power generation is the most commercial use of the most promising technology. According to the different ways of condensing, the condensing Solar-thermal power generation can be further divided into two systems: point focusing and line focusing. The point focusing system mainly includes tower type Solar-thermal power generation and disc type Solar-thermal power generation. The line-focusing system mainly includes trough Solar-thermal power generation and linear Fresnel Solar-thermal power generation

3.1. Principle of solar thermal power generation

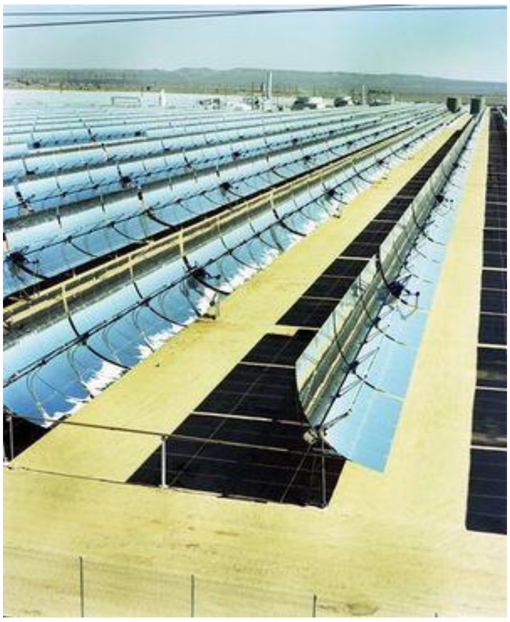
Solar thermal power plants are electricity generation plants that utilize energy from the Sun to heat a fluid to a high temperature. This fluid then transfers its heat to water, which then becomes superheated steam. This steam is then used to turn turbines in a power plant, and this mechanical energy is converted into electricity by a generator. This type of generation is essentially the same as electricity generation that uses fossil fuels, but instead heats steam using sunlight instead of combustion of fossil fuels.[2] These systems use solar collectors to concentrate the Sun's rays on one point to achieve appropriately high temperatures. There are two types of systems to collect solar radiation and store it: passive systems and active systems. Solar thermal power plants are considered active systems.[3] These plants are designed to operate using only solar energy, but most plants can use fossil fuel combustion to supplement output when needed.

3.2. Types of Plants

Despite the fact that there are several different types of solar thermal power plants, they are all the same in that they utilize mirrors to reflect and concentrate sunlight on a point. At this point the solar energy is collected and converted to heat energy, which creates steam and runs a generator. This creates electricity.

3.2.1. Parabolic Troughs

These troughs, also known as line focus collectors, are composed of a long, parabolic shaped reflector that concentrates incident sunlight on a pipe that runs down the trough. The collectors sometimes utilize a single-axis Solar tracking system to track the Sun across the sky as it moves from east to west to ensure that there is always maximum solar energy incident on the mirrors. The receiver pipe in the center can reach temperatures upward of 400℃ as the trough focuses Sun at 30-100 times its normal intensity.[2]



These troughs are lined up in rows on a solar field. A heat transfer fluid is heated as it is run through the pipes in the parabolic trough. This fluid then returns to heat exchangers at a central location where the heat is transferred to water, generating high-pressure superheated steam. This steam then moves a turbine to power a generator and produce electricity. The heat transfer fluid is then cooled and run back through the solar field.

3.2.2. Parabolic Dishes

These are large parabolic dishes that use motors to track the Sun. This ensures that they always receive the highest possible amount of incoming solar radiation that they then concentrate at the focal point of the dish. These dishes can concentrate sunlight much better than parabolic troughs and the fluid run through them can reach temperatures upwards of 750℃.

In these systems, a Stirling engine converts heat to mechanical energy by compressing working fluid when cold and allowing the heated fluid to expand outward in a piston or move through a turbine. A generator then converts this mechanical energy to electricity.

3.2.3. Solar Towers

Solar power towers are large towers that act as a central receiver for solar energy. They stand in the middle of a large array of mirrors that all concentrate sunlight on a point in the tower. These large numbers of flat, sun tracking mirrors are known as heliostats. In the tower, there is a mounted heat exchanger where the heat exchange fluid is warmed. The heat concentrated to this point can be 1500 times as intense as incident sunlight. The hot fluid is then used to create steam to run a turbine and generator, producing electricity. One drawback with these towers is they must be very large to be economical.

4. BENEFITS AND DRAWBACKS

Because these systems can generate steam of such high temperatures, the conversion of heat energy to electricity is more efficient. As well, these plants get around the issue of being unable to efficiently store electricity by being able to store heat instead. The storage of heat is more efficient and cost-effective than storing electricity.

Additionally, these plants can produce dispatch able base load energy, which is important as it means these plants produce a reliable amount of energy and can be turned on or up at will, meeting the energy demands of society.[7] In addition to this, solar thermal power plants represent a type of electricity generation technology that is cleaner than generating electricity by using fossil fuels. Thus, these are some of the cleanest options for generating electricity. Despite this, there are still associated environmental effects of these plants as a full life cycle analysis can show all associated carbon dioxide emissions involved in the building of these plants. However, emissions are still much lower than those associated with fossil fuel plants.

Some of the drawbacks include the large amount of land necessary for these plants to operate efficiently. As well, the water demand of these plants can also be seen as an issue, as the production of enough steam requires large volumes of water.[8] A final potential impact of the use of large focusing mirrors is the harmful effect these plants have on birds. Birds that fly in the way of the focused rays of Sun can be incinerated. Some reports of bird deaths at power plants such as these amounts the deaths to about one bird every two minutes.

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