Summary of gas turbine power generation technology based on solar power

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Abstract. With the increasing pressure of energy shortage and the environment pollution, it’s important to take the advantage of the renewable clean energy for newpower generation technology. Solar energy, as a kind of energy with a wide range of sources, has become a new type of clean energy with the most potential for development. This study introduces the project test and progress of solar gas turbine combined generation technology at home and abroad as well as the research status of key technologies. The key technologies of heat collection, heat storage and heat recovery are analyzed and summarized, it has been pointed out that the concentrator ratio achieved by the dish and tower is more than an order of magnitude higher than that of the linear Fresnel and slot; Thermochemical heat storage technology has the theoretical maximum energy storage density, the heat storage of chemical bonds is about 5 times of latent heat, 10 times of sensible heat, and has the advantages of stable chemical bonds, small energy loss and other advantages, energy storage in the future has more development advantages. At the same time, the future research direction of solar thermal power generation technology is prospected.

Keywords: solar energy; gas turbine; Power generation; review.

1. Preface
At present, we are faced with many practical problems such as energy shortage, greenhouse effect and environmental degradation. The development of new clean energy has become a hot topic of discussion and research in all walks of life [1]. As a kind of renewable energy source with a wide range of sources, solar energy has many advantages such as inexhaustible energy reserves and cleanliness of development and utilization, thus it has become the new clean energy with the most potential. Globally, North America, Africa, Australia, the Middle East and other regions have very rich solar energy resources, and their solar energy utilization technology is also relatively advanced. In the Midwest of China, With abundant solar energy resources, it is estimated that by the end of 2020, the installed capacity of solar power can reach more than one million megawatts [3].

Until now, the main forms of solar thermal power generation technology are solar thermal power generation and photovoltaic power generation. The development of photovoltaic technology has been relatively mature, and the research on solar thermal power generation technology is still in its infancy. The main principle of CSP technology is to attain solar thermal energy by using solar collectors, and then collect the collected solar thermal energy to heat the working water to generate steam. The steam enters the steam turbine for expansion work to generate electricity. Compared with photovoltaic
power generation systems, the advantages of CSP systems are lower system cost, higher power generation capacity, and higher efficiency [4]. The current solar thermal power generation technologies mainly include Fresnel type, trough type, dish type and tower type, and the thermal power conversion devices mainly include Stirling machines, steam turbines, gas turbines and the like. Among them, the gas turbine is more popularized and concerned because of its compact structure, short installation period, fast start-up, stable operation, high reliability, high efficiency, and low water consumption [5].

The Integrated Gas Combined Cycle (ISCC) is based on a conventional combined cycle power generation system. With the solar thermal field coupled. Through the complementary use of the two energy sources, solar energy utilization can be effectively improved. Efficiency, thereby reducing fossil energy consumption and pollutant emissions [4]. Therefore, the proposal of solar gas combined cycle power generation system has very important practical significance. This paper focuses on the current status of solar gas turbine combined power generation system and its key technology research progress.

2. Solar gas turbine combined power generation system

The iscc system was first proposed by the American Electric Power Research Institute in the 1980s [10], that is, by generating electricity from solar power systems and gas turbines. The system is coupled to obtain a combined cycle system. From the early 1980s, the United States, Western Europe, Algeria, Japan and other countries began active research on solar thermal power generation technology [7]. From 1984 to 1990, the United States built the world's first trough solar thermal power station in Southern California, which has been in operation until now [11]. The EU launched the Solhyco project between 2006 and 2010, and established a 100 kW solar tower micro gas turbine cogeneration system. By using liquid biofuels to supplement combustion, the actual output power can reach 70 kW, and the power generation efficiency is about 25%. [15]. The ISCC power station in eastern Morocco has a total generating capacity of 250 MW and a sunglass area of 226,000 square meters. The annual generating capacity exceeds 1.78 billion kWh [12]. In recent years, with the further development of solar thermal power generation technology, the United States and the European Union have successively built a gas turbine power generation system with a higher concentration ratio and higher power generation efficiency. In the United States (BraytonEnergy), a solar-disc gas turbine power generation system was built in 2008-2011. The diameter of the dish mirror is 22.9m, and the heat sink can receive 230 kW [17] of focused solar energy. In 2013-2017, the European Union completed the solar-disc gas turbine distributed generation project OMSop, which has a gathering area of 97 square meters, a heatsink outlet temperature of 900 °C, an output power of 9 kW, and a power generation efficiency of 23%. [16]

Compared with the international research on solar thermal power generation technology, China's research in this field started late and lags behind the international level [6]. Affected by other countries and the trend of international energy utilization, China has also vigorously promoted the research of solar thermal power generation technology, and has made significant progress under the influence of relevant policies. At present, it has initially possessed certain international competitiveness. China's first iscc power station, Ningxia Yanchi, Hanas trough solar gas turbine combined cycle power station has been started construction in October 2011, with a planned capacity of 92.5mw. After completion, the annual power generation capacity can reach 3.4 10 8 kwh,. In June of 2012, the first solar gas turbine combined cycle power generation project developed by Xinjiang Ebihu Power Company was officially launched, with a planned installed capacity of 59Mw. The generating capacity of gas turbine is about the same as that of gas turbine. Solar power capacity accounts for 20% [18].

3. Progress in key technologies for solar gas turbines

The key technologies of solar gas turbine power generation system mainly involve concentrating heat collection, heat storage and heat recovery. The continuous optimization and improvement of these technologies is to promote the development of solar gas turbine power generation technology and is the key to determine the smooth, safe and efficient operation of the system.
3.1. Concentrator

The concentrator concentrates the solar energy with low energy density into high energy radiant energy, which accounts for 30%-50% of the total solar thermal power station. The concentration of the concentrating ratio has a direct influence on the heat collection temperature and system efficiency. The high concentrating ratio is a necessary condition for the high temperature and high efficiency operation of the collector receiver. Different concentrating ratios correspond to different optimal collector temperatures [9]. The linear Fresnel and trough concentrating ratio is generally one hundred or less, and the dish and tower type are more than an order of magnitude higher than the linear Fresnel and trough due to their structural characteristics. Dish and tower have greater potential for development in solar thermal power generation.

When a dish concentrator provides a high concentration of light energy, there are also some hot spots in the concentrating light, which causes serious problems such as damage to the collector or shortened life. The main reason for this problem lies in various errors of the concentrator, including: optical mirror error, slope error, installation error, structural deformation and tracking error. In the past few years, there have been many studies on the slope error and mounting error measurement of the mirror, as well as the mirror optimization adjustment. Pottler measured the specular coordinates of the concentrator using photogrammetry and calculated the slope error of the mirror to be approximately 1.6 mrad. Sandia Labs in the United States invented a stripe reflection method for disc mirrors, which uses LCD screens to display different stripe shapes, and then shoots the reflected strips through the camera. After conversion, the error distribution of the mirror can be displayed on a computer.

3.2. Collector

The collector receiver is one of the key components of a solar thermal power generation system that converts high-energy flow-density solar radiant energy into high-temperature heat. Therefore, the collector receiver usually works at high radiant energy flow density, high temperature and high pressure, and its life and working efficiency directly determine the performance of the entire thermal power generation system.

Wang Zhifeng, a researcher at the Academy of Sciences, conducted a comparative study of a heat pipe vacuum tube collector and a flat solar collector, and found that the highest efficiency of the flat solar collector is slightly higher than that of the heat pipe vacuum collector, but the advantages of the vacuum tube collector is that when the heat collecting temperature is increased, the heat collecting efficiency fluctuates less and stabilizes at a higher level. In 2012, BraytonEnergy developed a coiled collector that can heat air to 960 °C, project heat to the heat sink of 270 kW, and achieve thermal efficiency of 86%. The heat sink has been used in Disc gas turbine system [21]. The Swiss ETH Academy has designed a volumetric heat sink for solar gas turbines with a ring-shaped foam ceramic inside and without a cover plate that raises the air temperature to 1251 °C. Xiao et al. From Zhejiang University proposed a rotating particle collector receiver system that uses an electromagnet to generate vibrations that drive particles along a helical surface while the particles are heated by focused sunlight. The experimental results show that the particles pass through a single pass. The heating can reach above 600 °C, and the simulation results show that when the incident energy density reaches 160 kW/m², the rotating particle temperature can reach about 1100 °C. Due to its good high temperature and heat storage characteristics, particle collectors have attracted more and more attention. At present, particle collectors are various in form, but most of them are in the experimental research stage, and further research is needed.

3.3. Heat storage

Heat storage is the process of storing solar radiation energy in other forms of energy. Heat storage can improve system stability and energy efficiency, and reduce costs. This is also a major feature of solar thermal power generation over photovoltaic power generation. According to the form of energy storage, heat storage can be divided into sensible heat storage, latent heat storage and thermochemical storage.
Since the storage density of latent heat storage is significantly greater than the storage energy density of sensible heat storage, its technical breakthrough difficulty is currently much lower than that of thermochemical storage, making it the most popular thermal storage technology. Three-phase solid solution ceramics (SrTi03X0.65BaTi030.35Bi0.5Na0.5Ti03) proposed by Yang et al., whose storage density is as high as 1.40 J/cm3, and the heat storage efficiency is higher than 90%. Tokyo University of Tokyo, Tokoro et al. developed a new solid-solid phase change material capable of storing heat for a long time in 2016. They call it heat-storage ceramic. This material is strip-shaped five. The thermal storage mechanism of trititanium oxide is: under the pressure condition (60 MPa), the strip-like pentoxide phase becomes pentoxide pentoxide and releases latent heat, which is 230 kJ/L; The trititanium pentoxide phase becomes a strip of \( \lambda \) pentoxide pentoxide, thereby achieving heat storage.

Thermochemical heat storage technology has the theoretical maximum energy storage density, the chemical storage of heat is about 5 times of latent heat, 10 times of sensible heat, and has chemical bond stability and small energy loss. The equipment involved is compact and low in cost. It is also highly effective, so it is also attracting attention. Agrafiotis et al. used X-ray diffraction (XRD), differential thermal analysis (DTA), scanning electron microscopy (SEM), and differential scanning calorimetry (DSC). The co3 o4/co4 metal oxide pair was tested and analyzed, and the results showed that the reaction rate had a great influence on the reaction. In 2014, The Southern Research Institute (SRI) received US$1.05 million from the US Department of Energy to develop a new high-temperature thermochemical thermal storage system that uses reversible chemisorption/desorption reactions to store and utilize thermal energy. The normal operating temperature of the system can be reached at 900 °C, the storage density exceeds 1 MWh/m3, which is only 0.25-0.40 MW h/m3 compared to the existing molten salt system.

3.4. Reheat
Regeneration is the process of recovering the residual heat energy of the tail gas of a solar gas turbine. Since the gas turbine has a high exhaust gas temperature, energy recovery and utilization can improve energy utilization. At present, common regenerative technologies include steam regenerative, chemical regenerative and air reheating.

American GE’s lm5000 steam reinjection gas turbine uses a steam injection cycle to increase the overall thermal efficiency of the system from 36% to 43%. Roberto Carapellucciet al. optimized the chemical regenerative cycle in 2004 and proposed two improved methods, and pointed out that the thermal efficiency of the chemical regenerative cycle under a single-pressure steam reformer can reach 52.4%. Jinhongguang couples low-temperature solar energy with fossil fuels to obtain high-grade fuel chemical energy by utilizing low-grade exhaust gas heat and medium-low temperature solar energy of gas turbines, which not only reduces the grade difference of energy transfer process, but also solves the problem of low conversion efficiency of solar fuel. Ni et al. proposed a two-stage chemical reforming solar gas turbine system based on the reaction characteristics and energy gradient utilization principle. The high temperature zone is to continue the reforming reaction of the unreacted mixture in the low temperature zone, and the low temperature zone is the exhaust gas. The steam generated by waste heat recovery is mixed with pressurized natural gas to produce CO and H2, and the overall power generation efficiency is expected to reach 47.8%, further increasing the proportion of solar power generation in the system.

4. Conclusion
This paper reviews the development history, current status and latest development of solar gas turbine combined power generation system, and expounds and analyzes the status quo and latest research results of key technologies such as concentrating heat collection, heat storage and heat recovery in the system. The following research was conducted on a solar gas turbine power generation system and related technologies.

System improvement and optimization: From the technical characteristics and development trends of solar thermal power generation, it can be seen that:
有多种类型的太阳能热发电技术，它们正逐渐进入商业化阶段。然而，目前成本高，仍有改进空间。提高效率和降低成本。

(2). 以提高太阳能热发电的运行温度，其效率越高，高温太阳能热发电技术是发展趋势。塔和碟型热电系统由于更高的运行温度，碟状和塔状达到的集热比远高于线性菲涅耳和槽。因此，碟状和塔状在太阳能高温度热发电中被使用。这有巨大的开发潜力。

(3). 如何解决聚光镜的光学误差、倾斜误差、安装误差、结构变形和跟踪误差，是进一步提高集热比和有效利用太阳能的一个重要方向。

在未来的创新中，储能技术的创新，储能介质的创新和储能模式的创新应是重点。储能介质的创新包括新材料的发展和现有材料的改进，是对不同储能形式的组合。例如，混合储能不仅创新储能模式，也专注于解决储能系统的实际问题。

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