

Analysis on Application Prospect of Heat Storage Solar Stirling Generator

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Received: May 24, 2017 / Accepted: June 08, 2017 / Published: July 31, 2017

Abstract: The heat storage solar Stirling generator referred in this paper is a power conversion unit integrating sunlight receiver, regenerative chamber, Stirling engine and generator, which increases a heat storage function relative to similar power conversion units. This power conversion unit adopts invention patents authorized in China in recent years to apply to dish solar Stirling thermal power system, and it will be sure to become a principal part of future energy internet and the optimal technical route of CSP (concentrating solar power). The trough system rests on that Stirling generator substitutes the steam turbine to desalt seawater by remaining heat during power generation. Accordingly, the tower system will be rejected.

Key words: Solar energy, power generation, Stirling generator.

1. CSP (Concentrating Solar Power) Technology and Industrial Status

In order to acquire a clean energy, the utilization of solar energy for power generation is a dream of the human being, and CSP is an important development direction. Currently, CSP involves trough system, tower system and dish system. The trough system has realized its commercialization, but the tower system and dish system are still in the demonstration stage. Both the existing trough and tower systems transfer solar energy into steam energy to drive a steam turbine for power generation, which can be performed day and night by stored heat; the current dish system adopts solar energy to drive Stirling generator for power generation without heat storage, and the power generation is only performed in the daylight, because a modern Stirling generator is characterized by complex structure, large volume and difficult heat storage [1].

Therefore, the technical difficulty of CSP popularization and application consists in resolving

heat storage at a low cost.

Even though both trough system and tower system can resolve the heat storage problem, either heat transfer oil or fused salt is very expensive and the cost for power generation rises proportionally. The existing dish system is completely incapable of heat storage, so solar power generation is performed only in the daytime. The invention patent in China authorized on August 19, 2015 is titled as “A heat storage solar stirling generator”, which makes use of the compact-structure advantage of Stirling reversible heat engine to establish a heat storage chamber at the heat-inflow end. The heat storage media in the heat storage chamber cannot flow, and the heat flows in the heat storage chamber by virtue of temperature difference among media. In the daytime, some solar energy after conversion into heat energy drives Stirling generator for power generation, the rest heats the heat storage media so as to raise the temperature; at night, heat stored in high temperature heat storage media drives the Stirling generator for power generation and the temperature of heat storage media falls. The adoption of a dish system for such Stirling generator, with all advantages of trough system, tower

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system and dish system, reduces the manufacturing cost and operation expense [2].

The existing Stirling heat engine technology is completely able to guarantee a successful research and development of heat storage solar Stirling generator. Based on design theories for Stirling reversible heat engine which have been established, structural parameters and operation parameters can be computed and confirmed precisely according to actual demands [3, 4]; the main structure and two-level seal technology for Stirling reversible heat engine put a complete end to working medium leakage, with a compact structure, and a heat storage chamber is arranged at the heat-inflow end to make sufficient use of the space in the middle of the cylinder [4]; the control system of Stirling generator can control the startup, brake and working condition adjustment, which is a reliable technology for controlling power generation and heat storage solar energy distribution proportion [5]; the fixation of thermal rotors and design of piston assembly depend on reasonable patent-based technical schemes [6]; its regenerator which is a key component adopts a patent technology for reversible heat exchange between two working chambers (phase difference: π) to achieve a reasonable heat utilization [7]; the heat-outflow end carries out a natural cooling which can be widely applied to water deficiency areas; the dish system, relative to trough system and tower system, has two advantages including high heat engine efficiency and modular assembly, which will be exerted sufficiently.

During the energy crisis in the 1970s, American Government invested huge funds in Boeing Company to establish a team which researched a dish solar power generation system and developed a 20 kw Stirling generator. Due to technical and economic causes, however, the industrialization was not realized. In September 2012, the first dish Stirling photothermal demonstration power station established by Sweden Cleanenergy in Inner Mongolia was put into formal operation. Subsequently, domestic

enterprises, such as Xi'an Aero-Engine Plc, Shanghai Qiya Power Technology Co., Ltd, Xiangtan Electric Manufacturing Co., Ltd, Dalian Honghai New Energy Development Co., Ltd and so on, have stepped in the development of dish solar Stirling thermal power generation system. However, these companies have failed to properly settle the heat storage problem of dish solar Stirling thermal power generation system, so Stirling generator has no the function of heat storage.

2. Heat Storage Solar Stirling Generator

Dish solar Stirling generator system is mainly composed of dish condensing lens, sunlight receiver, Stirling engine and generator, of which the entirety composed of solar receiver, Stirling engine and generator is referred to as CPU (power conversion unit) [1]. Heat storage solar Stirling generator is just to increase a regenerator chamber in the CPU so that it has a heat storage function. Stirling reversible heat engine is integrated with engine and generator, with a compact structure, so that there is a space for heat storage chamber at the heat-inflow end and the generator and air-cooling radiator are just arranged at the heat-outflow end [4]. The heat storage chamber is placed in the middle of the cylinder at the heat-inflow end, and the vacuum heating lens of the heat storage chamber is installed on the heat-inflow end surface. There is a heat-inflow end cylinder and a regenerator connecting pipe as well as heat storage media in the heat storage chamber. The outside surface of the heat storage chamber is wrapped with a heat-insulating layer, so is that on the outside surface of the cylinder at the heat-inflow end. Pistons at two ends of the piston assembly are respectively inserted in cylinders at heat-inflow end and heat-outflow end. The heat engine rotors are placed in the middle of the heat engine body and the piston assembly is clipped on the heat engine rotors. The generator is placed in the level-II seal chamber which is in the middle of the cylinder at the heat-outflow end and the rotating shaft

of the generator is connected with the rotor axis of the heat engine. One end of the regenerator is connected with the cylinder at the heat-inflow end via the cylinder at the heat-inflow end and regenerator connecting pipe and the other end is connected with the cylinder at the heat-outflow end through the cylinder at the heat-outflow end and regenerator connecting pipe to form a working chamber. Here a single-loop connection or multi-loop connection is available. The control system is connected with the working chamber via the cylinder at the heat-outflow end and regenerator connecting pipe. The vacuum heating lens aims to vacuumize the space between glass and heat storage chamber so that sunlight can penetrate the glass and vacuum heating storage chamber and block heat from transmitting to the glass. Its working principle is the same as the vacuum heating pipe of trough system. Heat storage media are solid or liquid substances or solid-liquid mixtures. The control system can realize the startup, brake, speedup and slowdown. The cylinder at the heat-inflow end is made of material with good thermal insulation and that at the heat-outflow end is made of material with perfect heat conductivity [2], so as to reduce the heat dissipation from the cylinder at the heat-inflow end as much as possible and ensure the fast radiation from the cylinder at the heat-outflow end.

The CPU equipped with heat storage chamber above is installed in the dish solar Stirling generator system, so that solar beams penetrate the vacuum heating lens to heat fused salt, solid heat storage media, cylinder at the heat-inflow end and regenerator connecting pipe, and then raise the temperature in the heat storage chamber. After the temperature reaches the working temperature, the control system starts Stirling engine to drive it for power generation. Afterward, the electric energy is transmitted to the power grid. In the daytime, the control system stores heat while generating power; at night, it regulates the power generation according to temperature reduction to keep a balanced output; when the temperature in the

heat storage chamber is lower than the minimum working temperature, the control system stops for the temperature preservation. During the startup, the control system sends a signal that high-pressure working media are injected to the working chamber in the isothermal expansion process, high-pressure working media flow into the working chamber to sharply raise the pressure and break the pressure balance among working chambers, then the engine starts to run. The control system controls the output power by controlling the minimum working pressure of working chambers according to the working temperature. When the temperature in the heat storage chamber is low, the control system injects working media to working chambers to raise the minimum working pressure and stabilize the output power. In the event that the heat storage chamber reduces to the minimum working temperature, the control system sends a signal that high-pressure working media are injected to the working chamber in the isothermal compression process, after the high pressure working media flow into it, the working chamber in the isothermal compression process rises to the pressure of that in the isothermal expansion process, then the pressures among working chambers are balanced and the engine stops running to enter its heat preservation [2].

The heat storage solar Stirling generator makes use of multiple invention patents authorized recently by China, with advanced technologies and better development and application prospects.

3. Application Prospect of Heat Storage Solar Stirling Generator

The CPU of the dish solar Stirling generator system is increased with a heat storage function so that the dish system perfectly resolves all difficulties impossibly-settled by trough system and tower system, and it is a necessary technical scheme for CSP in becoming basic electric power.

A dish solar Stirling thermal power system which

can store heat will be the principal part of the future energy internet. Dish solar Stirling generator systems which are distributed on two sides of roads and railways as well as the deserts and desolate hillsides are connected by energy internet to focus on the regulation of heat storage and power generation time of dish solar Stirling generator systems so that the energy internet always stays in a high efficiency and high quality power supply state. Furthermore, hillside, road-insulating area and so on, which are not used for trough system and tower system, can be taken as construction land for dish system to improve the comprehensive utilization of land resource. In case of oceanic islands far away from public electric grids and remote mountainous areas, the dish solar Stirling generator system which can store heat can store the daytime solar energy for power generation and supply at night to form a self-generating and supplying single power generation system or small sealed electric grid. If equipped with a Stirling heat pump sea water desalting device [8], the electric power generated is used to produce freshwater, which can resolve freshwater problem for islands and remote mountainous areas, but it is not available for trough system and tower system. As for technical and economical efficiency, environmental protection, investment scale and risk control, etc., however, the dish system which can store heat is more advantageous than trough system and tower system.

The efficiency of dish Stirling heat engine is higher than steam turbine heat engine for trough system and tower system, with natural technical advantages. The dish system which can store heat adopts heat storage technology with heat flow and heat-storing medium stagnation to save the electric power driving the flow of heat storage media, eliminate risks that heat storage media incur the equipment out of use due to low temperature solidification and so that the operation is safe and reliable. Stirling generator which is a key device for dish system is featured by simple structure, fewer parts and components, complexity and

quantitative production cost much lower than internal combustion engine. The high price of the existing Stirling generator is because of unreasonable technical schemes and smaller production lot. The dish system which can store heat has no “three wastes” discharge and adverse effects on the environment. In deserts with lack of water, trough system and tower system fail to generate power due to water shortage while the dish system which can store heat can generate power normally. The modular advantage of dish system can effectively control the investment scale and risk.

In summary, CSP technology is staying in the key stage for selecting technical routes of dish system, trough system and tower system. The invention of heat storage solar Stirling generator has made a reasonable selection of such three technical routes: the optimal technical route for CSP focuses on dish solar Stirling thermal power system which can store heat; the trough system is to substitute the steam turbine with Stirling generator so as to desalt seawater by remaining heat while generating power [9]; the tower system will fall into disuse.

References

- [1] Zhu, Ch. Y., and Peng, X. F. 2011. “Technological Development of Dish Stirling Solar Power Generation.” *Power & Energy* 32 (6): 507-11.
- [2] Kong, L. B. 2015. A heat storage solar Stirling generator. China Patent Gazette.
- [3] Kong, L. B. 2014. A high temperature gas-cooled reactor nuclear power generation and seawater desalting device. China Patent Gazette.
- [4] Kong, L. B. 2009. “Level-II Sealed-Type Stirling Reversible Heat Engine.” *World Sci-Tech Research and Development* 31 (6): 1016-9.
- [5] Kong, L. B. A Stirling heat engine operating condition controller. China Patent Gazette.
- [6] Kong, L. B. 2011. A solar Stirling generator. China Patent Gazette.
- [7] Kong, L. B. 2012. A Stirling heat engine heat exchange regenerator. China Patent Gazette.
- [8] Kong, L. B. 2013. A Stirling heat pump seawater desalting device. China Patent Gazette.
- [9] Kong, L. B. 2014. A Stirling generator for desalting seawater by remaining heat. China Patent Gazette.