A REVIEW ON SOLAR THERMOELECTRIC COGENERATOR WITH EVACUATED TUBE SOLAR COLLECTOR

N.S.Sathawane[1], Dr. P.V.Walke[2]

[1] M. Tech,Heat power engineering, [2]Head of the Department,

Mechanical Engineering Department, G. H. Raisoni College of Engineering, Nagpur.440016 (India)

ABSTRACT

Thermoelectric materials are able to convert heat to electricity directly by the movement of charge carriers across a thermal gradient and are thus an attractive means of generating electrical power from solar radiation. Compared to conventional electrical power generator systems, thermoelectric generators theoretically offer many advantages, such as being simple in design and having no moving parts [16] or need for heat transfer media making them highly reliable as well as environmentally friendly. The challenge for the practical application of solar thermoelectric generation system (STGS) is lowering the cost and increasing the solar conversion efficiency of the system. The conversion efficiency of the thermoelectric module influences the overall cost and efficiency significantly. The practical approach for achieving the above aims is to generate thermal energy and electrical power simultaneously with the one system; that is, use cogeneration.

Keywords: Evacuated Tubes, See-Back Effect, Thermo-Electric Generator, Solar Collectors

I INTRODUCTION

The reserves of fossil fuels are diminishing and their combustion leads to environmental pollution. This stimulated the fast growth of solar energy application. A large portion of this energy is used in the form of heat, such as solar water heaters at homes and in industrial process heat applications. The solar energy is available in abundance and has potential to meet the current heating and electricity needs. However in most cases the solar systems are limited to providing either heat or electricity. Recently, hybrid systems are developed, either with photovoltaics or thermoelectrics to generate both electrical power and thermal energy or heat. Thermoelectrics have large potential to become an alternative power source for electrical power supply, as they could provide co-generation system anywhere thermal gradients exist.

II REVIEW OF SOME RESEARCHERS

Daniel Kraemer et al., [1] demonstrated a flat-panel solar thermal to electric power conversion technology based on the Seebeck effect and high thermal concentration. He uses high-performance nanostructured thermoelectric materials and spectrally-selective solar absorbers in an innovative design that exploits high thermal concentration in an evacuated environment. He achieved a peak efficiency of 4.6% which is 7-8 times that of the best-reported value by Telke's [12]. In Telke's devices air convection causes most of the heat loss which leads to a low optical-thermal efficiency. This heat loss is eliminated by enclosing the device inside a vacuum. These flat panel solar thermoelectric generators do not require any tracking system. It can be a cost effective technology to convert solar energy into electricity.

Ning Zhu et al., [2] developed a small power generation system making use of parabolic solar collector, the thermoelectric generator and the battery. The solar light is collected by the parabolic solar collector and focused on the thermoelectric generator, mounted at the focus point of parabolic solar collector. The temperature difference is developed between the hot side and the cool side. One side of the thermoelectric generator is heated (hot side) while other side's temperature is kept lower (cool side), causes the thermoelectric generator to generate the electricity. This electricity will be stored into the battery. In this system the maximum temperature difference reached to about 202 degree.

M. Eswaramoorthy et al., [3] conducted an experimental study on small scale solar parabolic dish thermoelectric generator. The solar parabolic dish collector is fabricated using an unused satellite dish antenna fitted with polished aluminum sheet as concentrator surface. Thermoelectric generator is placed on the focal plane of manual tracking parabolic dish collector. The concentrated solar radiation and water cooled heat sink is the driving potential to generate electricity. The operating parameters such as receiver plate temperature, power output and conversion efficiency are studied with respect to solar radiation. The experiment shows that receiver plate temperature, power output and conversion efficiency are varies directly with the solar radiation.

Yuan Dengal., [4] fabricated a solar-driven hybrid generation system (HGS) which consists of a silicon thin-film solar cell (STC), thermoelectric generators (TEGs) and a heat collector. Solar cell absorbs parts of the solar energy and directly converts it into electric energy. The waste heat from solar cell and parts of the solar energy are collected by the heat collector and conducted to TEG to produce thermoelectric conversion. The integrated design of heat collector between solar cell and TEG is key, to reduce energy losses. The total amount of generated power obtained is 393 mw in hybrid generation system, which is about 107.9% compared with that of the single STC and is even more than previously reported such HGS results [15].

Randeep Singh, et al, [5] discussed the combined system of thermosyphon and thermoelectric modules for the generation of electricity from low grade thermal sources like solar pond. The temperature difference between the lower convective zone and the upper convective zone of solar pond is available in the range 40–60 °C which can be applied across the hot and cold surfaces of the thermoelectric modules to generate power. He designed the system that utilizes gravity assisted thermosyphon to transfer heat from the hot bottom to the cold top of the solar pond. Thermoelectric cells are attached to the top end of the thermosyphon maintaining differential temperature across them. A laboratory scale model based on the proposed combination of thermosyphon and thermoelectric cells was fabricated and tested under the temperature differences that exist in the solar ponds.

Result shows that the system is able to provide useful power output at night time or on cloudy days because of the thermal storage capability of the solar pond.

Yadollah Faraji et al, [6] presented theoretical analysis of using thermoelectric modules for clean power electric generation, when coupled with evacuated tube solar collectors (ETSC). The system consists of eight evacuated tube solar collectors, 24 bismuth telluride based TEGs, a heat transfer system, and a thermal heat storage tank. The heat transfer fluid will pass through the heat Transfer systems & TEGs, under a counter-flow configuration to maintain a reasonable temperature difference across the TEGs and maximize the efficiency. The detailed design of cogeneration system is provided for electric power as well as hot water. The experimental analysis shows that 45W electrical output can be produced with just 24 TEG units and a hot water flow rate of 2 liters per minute at 92^{0}C. The conversion efficiency achieved was 5.7%.

Siddig A. Omer et al, [7] presented the design procedure and thermal performance analysis of a two stage solar energy concentrator which is suited to combined heat and thermoelectric power generation. The concentrator consists of a primary one axis parabolic trough concentrator and a second stage compound parabolic concentrator mounted at the focus of the primary. The thermoelectric device is attached to the absorber plate at the focus of the secondary. A cooling tube fitted to the cold side of the thermoelectric device to extract waste heat and maintain a high temperature gradient across the device to improve conversion efficiency. Results indicate that the second stage compound parabolic concentrator of the proposed design, in addition to improving the concentration efficiency, also inhibits convective air movement and thus improves the overall performance of the solar concentrator.

Wei He et al, [8] presented an experimental and analytical study on incorporation of thermoelectric modules with glass evacuated-tube heat-pipe solar collectors which can be used for combined water heating and electricity generation. The prototype unit comprises a glass evacuated-tube, a heat-pipe and a thermoelectric module with its one side attached to the condensation section of the heat-pipe and other side attached to a water channel. The heat-pipe transfers the solar heat absorbed within the glass evacuated-tube to the thermoelectric module. He presented a mathematical model of the solar heat-pipe/thermoelectric module (SHP-TE) unit to predict the thermal and electrical performance of the system for given solar irradiation, ambient water temperatures, geometrical and thermoelectric parameters. Results shows that the SHP-TE system has 1-2% electrical efficiency compared with an organic Rankine cycle system with about 3-4% electrical efficiency [13].

Ming Zhang et al., [9] demonstrated a pilot solar STECG system, which is based on incorporation of thermoelectric modules with evacuated solar tubes, for supplying electric power and hot water simultaneously. Also presented details of the thermal losses, evacuated tubular solar collector efficiency and electrical efficiency of the STECG, using an energy balance and heat transfer theory. Capital costs for constructing the STECG are also outlined in this paper. Results of the experiment shows that (Fig. a), as the solar insolation increases, the temperature across the thermoelectric modules (TEM) increases. The temperature difference across the TEM is proportional to the heat transfer rate which improves the thermal electromotive force generated by the Seebeck effect. So the electric power and electrical efficiency (Fig. b) of the STECG increases sharply with increasing solar insolation. The pilot experiment generated 0.19 kW h of electrical power and about 300 lit of hot water at 55^{0}C in 1 day when ZTM = 0.59 and solar insolation was less than 1000 W/m^2.

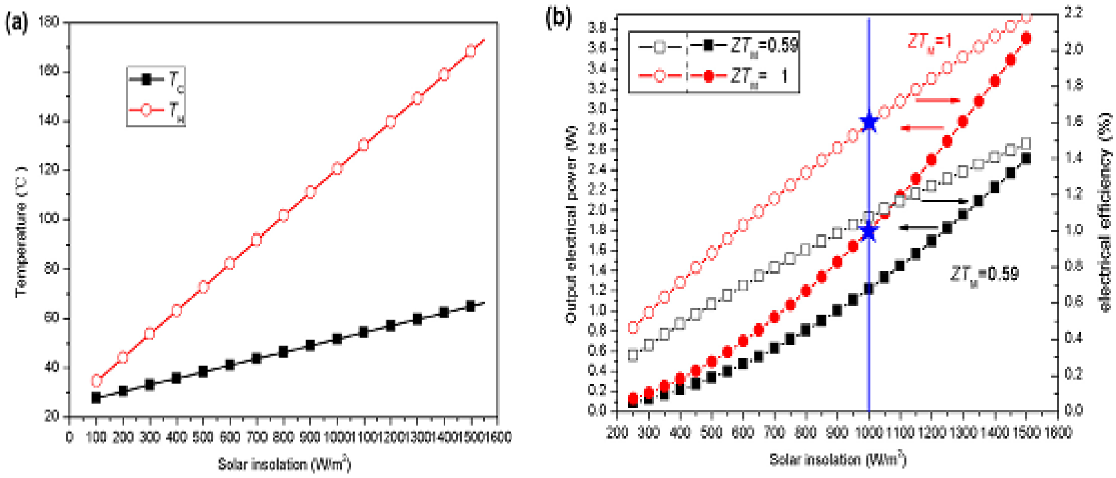

Fig. (a) Temperatures of the hot and cold sides of a TEM as a function of solar insolation;

Fig (b) output electrical power and electrical efficiency as a function of solar insolation.

Maria Theresa de Leon et al [10] designed a solar micro-thermoelectric generator with a lens, concentrating solar radiation onto the membrane of a thermoelectric generator (TEG). The solar radiation is focused which increases the input heat flux leading to an increase in temperature gradient across the device. The SOI wafer's device is used as the first thermoelement and aluminum as the second thermoelement in the thermoelectric generator (TEG) design. The design also involves the addition of isolation trenches for electrical insulation. The performance of solar thermoelectric generator (TEG) is investigated by developing an analytical model based on energy balance and heat transfer equations with varying geometries, lens parameters, and external conditions. The improvement in efficiency is observed by increasing both the concentration factor and the absorptance of the TEG membrane.

Edgar Arturo et al [11] performed an experimental study on a solar concentrating system based on thermoelectric generators (TEGs). The electrical generating unit with 6 serially connected thermoelectric generators (TEGs) using a traditional semiconductor material, Bi_2Te_3 were used, which was illuminated by concentrated solar radiation on one side and it is cooled by running water on the other side. A solar tracking system with concentrator made of amosaic set of mirrors was used. Two pairs of radiation sensors, a differential amplifier, and two servomotors were used to achieve its orientation towards the sun. Around 200^{0}C and 50^{0}C temperatures are achieved at hot side and cold side of the thermoelectric generators (TEGs) respectively, at midday. The optimal working conditions are achieved by designing the thermosiphon cooling system that absorbs the heat passing through the thermoelectric generators (TEGs). The system generates 20W of electrical energy and 200W of thermal energy stored in water with temperature of around 50^{0}C. The maximum electric efficiency of the system is 5%, which agrees with the estimations made in [14].

III CONCLUSION

From this review, various ways of using thermoelectric power generation system were reviewed. The most efficient way for improving the performance of thermoelectric power generation systems is to use it with hybrid systems. As discussed in this paper thermoelectric module can be used with flat plate collectors, parabolic collectors and pabolic dish or evacuated tube collectors to generate heat and electricity simultaneously. Such hybrid system improves the overall performance of the thermoelectric power generation system which can be made cost effective.

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