INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2017) 1–4

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

Heat pipes thermoelectric solar collectors for energy applications

Gunay Omer [a], Abdullah Hakan Yavuz [b,*], Rasit Ahiska [c]

[a] TES Ltd Co., Ankara, Turkey
[b] Faculty of Engineering and Natural Sciences, Gaziosmanpasa University, Tokat, Turkey
[c] Department of Physics, Faculty of Science, Gazi University, Ankara, Turkey

ARTICLE INFO

Article history:
Received 29 October 2016
Received in revised form
6 January 2017
Accepted 23 January 2017
Available online xxx

Keywords:
Thermoelectric
Heat pipe
Solar collector
Renewable energy
Efficiency

ABSTRACT

This study investigates the load characteristics of heat pipe thermoelectric solar collector (HPTSC) in practice. Heat pipe thermoelectric solar collector converts the heat generated by the Sun directly into electrical energy and produces hot water as well. The maximum power in HPTSC is obtained when the internal resistance of the thermoelectric module is equal to the load resistance. It has been observed to be possible to produce both hot water and electricity by improving available solar collectors or producing new generation HPTSC. While it is possible to generate an electrical power of 160 W from a HPTSC of one square meter using the thermoelectric method, the power produced with an average photovoltaic panel with the same area is only 132 W. Accordingly, HPTSC is a superior alternative not only to available solar collectors, but also to available PV panels. HPTSC, involving three different technologies, is environmentally friendly and certainly a product that allows for more efficient use of solar energy.

Introduction

In parallel with rapidly increasing population growth and industrialization increase the need for energy in the world and the vast majority of the energy used is generated from fossil fuels, which are harmful to the environment. Fossil fuel-based energy use causes considerable negativities such as foreign-source dependency, high import expenses and environmental issues and together with the depletion of world fossil fuel reserves, these negativities increase the importance of renewable energy sources.

The Sun, the source of all energy sources is the cleanest type of energy. The two main effects of the solar energy are the thermal effect and the radiation effect. The radiation effect is converted to electrical energy via photovoltaic panels, whereas the thermal energy is converted to electrical energy using the thermoelectric method. Although photovoltaic panels are widely used in today's world, it is not possible to mention the use of thermoelectric solar panels. However, solar heat is widely used to heat water with solar collectors. Solar collectors are produced in many countries including Turkey and used to produce hot water. Solar collectors are available in many different models, powers and capacities [1,2]. However, only a small fracture of the heat collected by solar collectors is used to heat water. 60% of solar heat is discharged to the environment, which leads to pollution [3,4]. On the other hand, thermoelectric generator systems do not passes moving parts, have a simple structure, do not require maintenance, are durable, allow for temperature control,

* Corresponding author.
E-mail addresses: gunayomer84@gmail.com (G. Omer), hakan.yavuz@gop.edu.tr (A.H. Yavuz), rasitahiska@gmail.com (R. Ahiska).
http://dx.doi.org/10.1016/j.ijhydene.2017.01.132

Please cite this article in press as: Omer G, et al., Heat pipes thermoelectric solar collectors for energy applications, International Journal of Hydrogen Energy (2017), http://dx.doi.org/10.1016/j.ijhydene.2017.01.132

convert the heat directly to electrical energy and work silently, reliably and stably. Alongside these advantages, the biggest disadvantage of these systems is the decrease in efficiency about 5–10% when the temperature difference between surfaces of thermoelectric modules used in panels is 100 °C. However, even when the temperature difference increases a little bit, the efficiency of TE panels reach 30–40% [4]. From a commercial point of view, the cost of the electric power produced by PV panels is 1.5 W/€ on average, while the cost is 1.5 W/$ for TE panel. Power generated by the TE system is almost directly proportional to the temperature difference between the hot and cold sides. The cost of the direct heat to electricity power generator is lower than that of photovoltaics (PV) in terms of equivalent energy generated [5]. Therefore, TE panels are more advantageous than PV panels in terms of electricity production. The advantage is even greater considering the area occupied by both panel types [6].

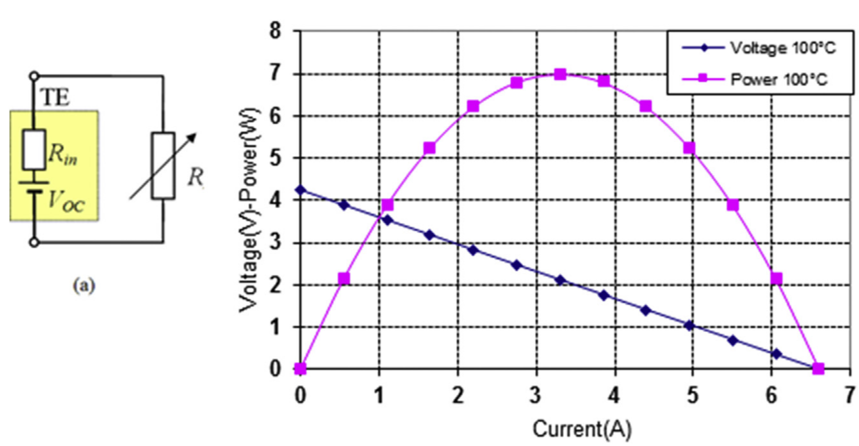
In this study, we designed, built and examined a heat pipe thermoelectric solar collector which converts the heat collected in the solar collector to electricity, thus protects the environment and allows for more efficient use of energy.

Basic structure of HPTSC

Heat pipes (HP) is the most effective methods heat insulation and heat transfer. Additionally, HPs are used to the thermal management of an integrated fuel cell and metal hydrogen tank system by thermal bridging increase hydrogen charge ratio [7,8]. HPTSC, involving three different technologies, is environmentally friendly and certainly a product that allows for more efficient use of solar energy. HPTSC consists of three different systems: a collector, a heat pipe and thermoelectric blocks [9]. The solar collector has a surface area of 0.5 m^2 covered with a special beam absorbing paint and a 50 l water tank. It was specially designed to allow for placing the dual heat pipe block, which transfers the collected heat to the thermoelectric module, into the collector. The heat pipe block consists of two custom-made heat pipes with an external diameter of 8 mm, a height of 80 cm and a power of 50 W. These heat pipes have a special structure which allows them to transfer the heat collected in the collector to the thermoelectric module (TEM). The thermoelectric block consists of a TEM with a dimension of 5 × 5 mm and a power of 10 W custom-designed by TES Ltd and placed on heat pipes with a special apparatus and a custom-developed heat pipe computer cooler which allows for maintaining the temperature of the cold surface of the module at the ambient temperature and provides maximum discharge of the heat from the surface.

TEs and their characteristics

The basic structure of a TEM is made up of thermocouples. Thermocouples are derived from combination of p- and n-type semiconductors and conductors. In a module, thermocouples are connected in series electrically and in parallel thermally. Modules work with the Seebeck effect. The Seebeck effect was discovered by Thomas Seebeck in 1821. The electrical circuit model of the thermoelectric module is shown in Fig. 1. The increase in electric current leads to an increase in power used in the internal resistance. A temperature difference occurs between the two surfaces of the thermoelectric module and if a load is connected, electric current passes through the load and electrical power is obtained. The maximum power is obtained from a TE when the resistance of the connected load is equal to the internal resistance of TEM. TEM output characteristic is shown in Fig. 1(b). When the temperature difference between TE surfaces is kept at a fixed value and the value of the connected load is changed, the power obtained changes as well. The maximum current is obtained when the load value is zero. The maximum voltage value is obtained when the load value is infinite. The maximum power is obtained when the resistance of the connected load is equal to the internal resistance of TE. Thus, load characteristics of the system are found. If the temperature difference between TEM surfaces is increased, the value of the power obtained increases parabolically [3,4].



$$P_{Lmax} = \frac{\alpha^2 \Delta T^2}{4R_{in}}$$

(b)

Fig. 1 – (a) The electrical circuit model of the thermoelectric module, (b) TE V-I chart.

Please cite this article in press as: Omer G, et al., Heat pipes thermoelectric solar collectors for energy applications, International Journal of Hydrogen Energy (2017), http://dx.doi.org/10.1016/j.ijhydene.2017.01.132