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THERMAL CHARACTERISTICS OF THE CONCENTRATOR PHOTOVOLTAIC HYBRID SYSTEM

Concentration of sun rays offers an attractive approach to increasing the efficiency of transformation of solar energy into electricity. Different types of sun concentrator systems are used at present. In this paper a Fresnel lens-based photovoltaic concentrator with the thermo-siphon type water cooling system is investigated. The temperatures at different points of the cooling system are measured. It is shown, that the proposed type of hybrid system can be successfully used.

Keywords: concentrating, solar, photovoltaic, thermal, heat, water.

Introduction

The use of solar energy converters in various sectors of the economy is a very important and priority issue. The conversion and use of solar energy is done mainly in two ways. The first of these is the conversion of solar energy into heat, and the second is the conversion of solar energy into electricity through semiconductor photovoltaic (PV) cells. Solar energy conversion systems are environmentally friendly and do not require high operating costs and are the most likely energy sources of the future.

The other promising approach to solar energy conversion and use is the application of concentrating PV (CPV) systems. The CPV systems are used to increase the efficiency of transformation of solar energy into electricity up to 40% and more. These systems consist of optical concentrators made of lenses or reflective mirrors and high efficiency multi-junction solar cells transforming the light energy into electricity. The CPV system consists of a tracker also to follow the sun during the day [1]. The solar cells of CPV system are cooled by heat sinks with air convection or by heat conductive fluid. The application of water cooling systems allows getting the additional energy in the form of heated water. In these systems the overall efficiency of the system is increasing obtaining the values up to 90% (about 40% - electric and about 50% - thermal components).

In this paper, the thermal performance of a CPV system with the thermo siphon water cooling is investigated.

The structure of the CPV system

The simplified structure of the CPV system with the Fresnel lens type concentrator is presented in Fig. 1. The solar light is concentrated by the Fresnel lens and absorbed by the high efficiency multi-junction solar cell. The system is tracking the sun to keep the solar rays perpendicular to the surface of the lens.

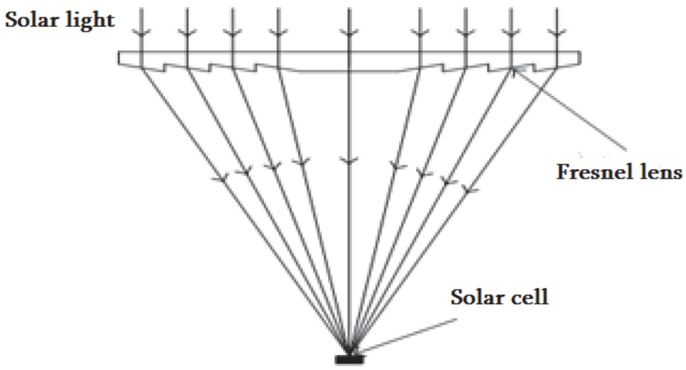

Fig. 1. The simplified structure of the CPV system

The heat from the solar cell is dissipated by the heat sink and air convection. The solar cell can be cooled also by the flow of a coolant through the tubes of the heat sink. Thus, in this system the two types of energies are generated: - electric and thermal mostly in the form of heated water. The heated water can be used for different needs. In this case the CPV system is operating as the PV and Thermal (PVT) hybrid system, and can be considered as the CPVT hybrid system.

The overall energy generated by the CPV hybrid system is determined as in PVT system as [1, 2]:

$$W = E + Q,$$

where *E* is the component of electric energy, and *Q* is the component of thermal energy. By dividing the left and right sides of this equation into the input energy of solar rays *Asun*, the efficiency of the CPV hybrid system will be obtained [3]:

$$\eta_{CPV} = \frac{E + Q}{Asun} = \eta_{el} + \eta_{th},$$

where $\eta_{el}$and η_{th} are the electric and thermal efficiencies respectively.

The electric component of efficiency of CPVT system is high (about 40%) in comparison with the efficiency of general flat plate PV modules which varies at present from 15 to 21%. Taking into consideration the thermal conversion also by CPVT hybrid system with the efficiency of about 50% or more, we can conclude that the CPVT hybrid system is a unique solar energy device with the highest total efficiency of solar energy conversion.

Experimental setup

For investigation of thermal characteristics of the CPVT hybrid system, an experimental laboratory model is prepared (Fig. 2). It consists of the multi-junction solar cell installed on the water-cooled heat sink (left side of the Figure). The heated water from the heat sink is flowing into the water accumulation tank with the volume of 3,2 l placed above the heat sink.

Fig. 2. The experimental setup of the CPV hybrid system

The parameters of the multi-junction solar cell, measured under STC conditions (1000 W/m^2 and 25 °C) are presented in the Table below.

Table

The electric parameters of the multi-junction solar cell

Parameter	Value	Unit
Efficiency	29	%
Maximum voltage	2,28	V
Maximum current	3,9	mA
Fill factor	86	%
Power	8,9	mW

In the middle of the experimental setup, the Fresnel lens is placed which is focusing the solar rays on to the solar cell. From the right side, the reflecting mirror can be seen. The mirror is tracking the sun in two directions automatically.

To measure the temperature of the heated water by CPVT hybrid system, four resistive temperature sensors are used. The sensors are placed as shown in Fig. 3.

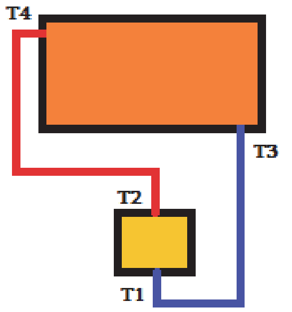

Fig. 3. The cooler, tank, manifold and thermal sensors on the tubes

The sensor TR1 is placed on the input tube and the TR2 on the output tube of the cooler (heat sink). In the upper side, the tank for accumulation of heated water with the sensors TR3 and TR4 is placed. The heated water by thermo siphon convection is flowing into the water tank.

Experimental results

The temperatures of the CPV hybrid system with water cooling circulation are monitored. As an example, 16 measurements conducted during a sunny day starting from 10:40 AM to 13:10 PM with the intervals of 10 min are presented in Fig. 4. In the horizontal axis are also shown the clean sunny hours from 10:40 to 12:40, and the appearance of clouds after 12:40 up to 13:10.

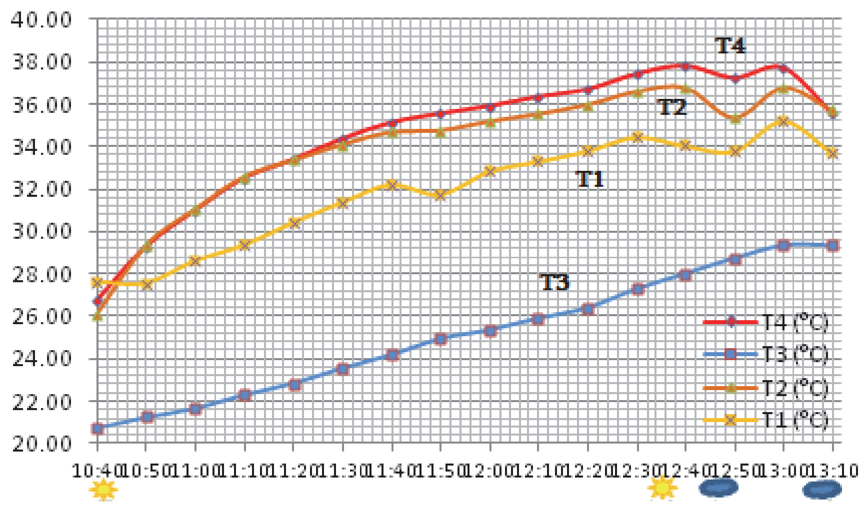

Fig. 4. Temperature characteristics of the CPV hybrid system

It can be seen from the Figure that the highest temperatures (T4) are obtained in the top of the inlet tube of the heated water accumulation tank. The lowest temperatures are observed in the outlet tube of the tank.

The difference of temperatures on the inlet and outlet tubes of the cooler is not very big in comparison with the heated water tank. It can be described by the comparatively small dimensions of the cooling element (tank) and by the fact that the cooler is illuminated by the concentrated solar light.

It can also be seen that the water temperature in the heated water tank is increasing rapidly from 26 °C to 36 °C, during two hours (from 10:40 to 12:40). Starting from the 12:40 the temperature in the tank is reducing slightly due to the appearance of clouds.

Conclusions

- Experimental results prove the usefulness of concentrator photovoltaic and thermal (CPVT) hybrid system for generation both electric and thermal energies with high efficiency.

- The developed type of concentrator photovoltaic and thermal hybrid system can be used successfully on the flat roofs of buildings for electricity generation and water heating.

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ՀԱՄԱԿԵՆՏՐՈՆԻՉ ՖՈՏՈՎՈԼՏԱՅԻՆ ՀԻԲՐԻԴԱՅԻՆ ՀԱՄԱԿԱՐԳԻ ՋԵՐՄԱՅԻՆ ԲՆՈՒԹԱԳՐԵՐԸ

Դիտարկվել է Արևի ճառագայթների կենտրոնացումը՝ որպես մոտեցում արևային էներգիան մեծ արդյունավետությամբ էլեկտրականի կերպափոխելու համար: Ներկայումս օգտագործվում են Արևի ճառագայթների կոնցենտրացման տարբեր եղանակներ: Ուսումնասիրվել է Ֆրենելի ոսպնյակների միջոցով կենտրոնացնող և ջերմասիֆոն տիպի ջրային հովացման համակարգով ֆոտովոլտային համակարգ: Չափվել են հովացման համակարգի ջերմաստիճանները տարբեր կետերում: Ցույց է տրվել, որ առաջարկվող տիպի հիբրիդային համակարգը կարող է հաջողությամբ օգտագործվել:

Առանցքային բառեր. կոնցենտրացված, արևային, ֆոտովոլտային, ջերմային, տաք, ջուր:

Р.Р. ВАРДАНЯН, А.Р. ХАРАКЕШИШЯН, М.Г. ТРАВАДЖЯН

ТЕПЛОВЫЕ ХАРАКТЕРИСТИКИ КОНЦЕНТРАТОРНОЙ ФОТОВОЛЬТАИЧЕСКОЙ ГИБРИДНОЙ СИСТЕМЫ

Концентрация солнечных лучей позволяет преобразовать солнечную энергию в электрическую с повышенной эффективностью. В настоящее время используются различные типы систем концентраторов Солнца. В данной работе исследуется фотоэлектрический концентратор на основе линзы Френеля с системой водяного охлаждения термосифонного типа. Измеряются температуры в разных точках системы охлаждения. Показано, что предложенный тип гибридной системы может быть успешно использован.

Ключевые слова: концентрирующий, солнечный, фотоэлектрический, тепловой, нагрев, вода.

УДК 621.317.733

Б.М. МАМИКОНЯН, Г.А. АВЕТИСЯН

ИССЛЕДОВАНИЕ ЧУВСТВИТЕЛЬНОСТИ ПРЕОБРАЗОВАНИЯ ПАРАМЕТРОВ НИЗКОВОЛЬТНЫХ КОНДЕНСАТОРОВ В ФАЗОВЫЙ СИГНАЛ

(Гюмри)

Рассмотрена измерительная цепь (ИЦ), предназначенная для преобразования в фазовый сигнал параметров низковольтных конденсаторов с малыми диэлектрическими потерями. Изложены методики расчета параметров элементов ИЦ и исследования чувствительности преобразования.

Ключевые слова: конденсатор, емкость, тангенс-дельта, фазовый сигнал, чувствительность преобразования.

Введение. Низковольтные конденсаторы, предназначенные для применения в радиоэлектронной аппаратуре, составляют около 25% от всех элементов схем [1], поэтому исследования, посвященные методам и средствам измерения их характеристик, продолжают оставаться актуальными.

Объект исследования. Основными параметрами конденсаторов являются номинальная емкость C_X и тангенс угла диэлектрических потерь $tg\delta$. Для широко используемых конденсаторов $tg\delta$ находится в пределах от 0,0005 (для фторопластовых) до 0,035 (для керамических) [2]. Значение $tg\delta$ зависит также от частоты переменного тока, на которой он измеряется: в основном его измеряют при частоте синусоидального тока 1000 *Гц*. Измерение C_X и