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PHOTOVOLTAIC THERMAL AS A HYBRID FORM OF OBTAINING ENERGY FROM SOLAR RADIATION

The work presents a method for hybrid connection of two systems used to obtain energy from solar radiation. The influence of temperature increase of the photovoltaic element on its efficiency was characterized. Two options for the construction of a system of the photovoltaic thermal type which are currently available for sale were presented. The advantages and disadvantages of connecting a collector installation with a photovoltaic installation were identified.

KEYWORDS: photovoltaics, solar collector, Photovoltaic Thermal, PV temperature

1. INTRODUCTION

An important problem raised in the media in recent years is energy security. The topic applies to all the producers and consumers of electric energy. Particular discussions conducted in relation to this subject already bear fruit in the form of a number of interesting initiatives. Their goal is both to introduce changes in the existing regulations as well as to develop the technology in order to increase production capacity. Constant increase of the demand for electric energy is visible, most of all, in the dynamically developing technology used to obtain energy from renewable sources. It is in them that the greatest hopes for assuring energy security are placed. Energy generation equipment from the RES (Renewable Energy System) group are characterized by higher and higher efficiency rates, and their process decrease to a level that makes them cost-effective from the consumer's point of view. Apart from the development of existing technologies, also attempts at combining them are made. One of them is combining two technologies of energy generation from solar radiation, referred to as the photovoltaic technology and the thermal technology.

2. OBTAINING ENERGY FROM SOLAR RADIATION

American scientists calculated a few years ago that the amount of energy that reaches our planet from the Sun every hour is equal to the amount consumed by all

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of human civilization in a year [8]. This means that solar radiation is an efficient source for obtaining energy. The technologies of solar collectors and photovoltaic panels have been independently developed in parallel for decades as part of solar power engineering [2].

In recent years, attempts have been made to combine the two different technologies in order to create a unified hybrid system. A photovoltaic thermal system (also known as a **hybrid PV/T system or PVT)** is a system which converts the energy of solar radiation into electric energy or thermal energy. The system generates mainly electric energy thanks to the photovoltaic effect and the same device produces warm water thanks to the phenomenon occurring in the solar collectors (in some versions of the system, the air is heated directly). The essence of such a combination of two systems that have operated independently till now is their mutual positive influence [1, 3]. A combination of those systems is presented on Figure 1.

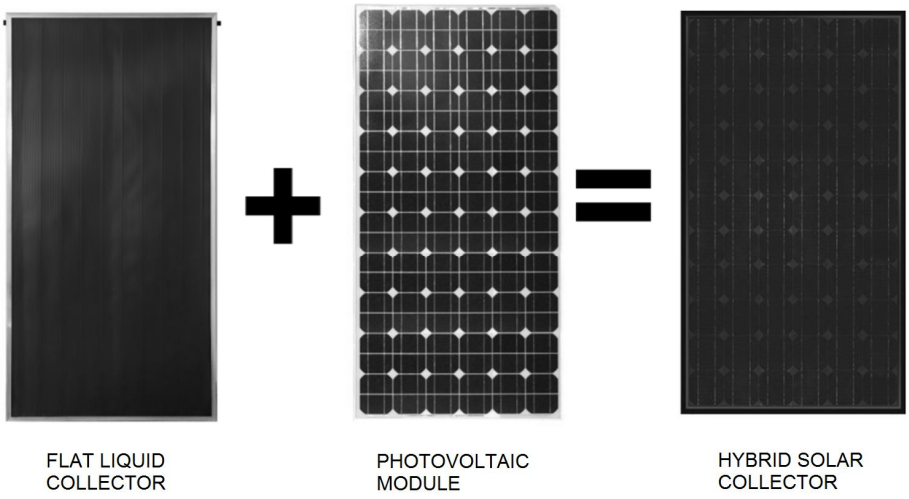

Fig. 1. Illustration of the combination of a collector with a PV module [6]

While analyzing the operation of a solar battery, it is important to remember that the increase of its temperature is always connected with the decrease of the value of the power obtained. This is caused by the increase of the frequency of vibrations of the atoms in the crystalline network that constitutes the structure of a photovoltaic cell. It should be added that vibrations of the crystalline network obstruct the flow of electrons which, in consequence, decreases the value of the electromotive force and, thus, reduces the voltage level [5].

In order to obtain energy from photovoltaic sources, one should remember that their nominal power is specified for the standard test conditions in which the temperature of the cell is 25°C. When the elements are heated by a certain value,

the power generation efficiency decreases. This dependency for a typical silicon solar battery is presented on Figure 2 [4].

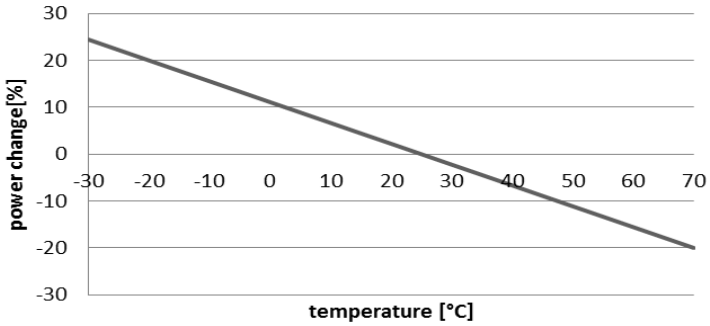

Fig. 2. The graph reflecting percentage fluctuation of the power of a typical solar collector in relation to temperature [5]

Co-operation of photovoltaics and solar collectors in a PVT system is focused on making the amount of electric energy generated from PV elements independent from their temperature. Cooling the cells makes it possible to increase the efficiency of their operation during hot days. Additionally, it should be remembered that the heat which, up till now, was considered as a wasteful and unwanted side effect, will now be used in an effective way.

3. TYPES OF PVT SYSTEMS

Hybrid systems can be divided into two groups depending on their construction.

Most of all, PVT systems based on the construction of a flat liquid collector can be distinguished. The photovoltaic cell is cooled in such a system by an absorber equipped with a heating coil in which the heating medium collecting the heat circulates. Installations of this type are connected to the building similarly to traditional solar collectors. The connection of a sample installation of PVT systems is presented on Figure 3.

PVT systems based on the construction of air heating collectors in which the collector is cooled by means of the air flowing under the photovoltaic cell are much less popular in Poland. Such a solution is much simpler and cheaper but it works only in specific types of investments where the heated air is needed, particularly during the summer months [7].

An example of such a solution is the “SolarDuct PV/T” system produced by the SolarWall company. Standard PV modules are fitted on a specially prepared frame. Both parts are matched in such a way that makes the air flow directly under the

modules. In this way, the cells will be cooled and the heat will be transferred to the heating and ventilation systems of the building by a special perforated absorber.

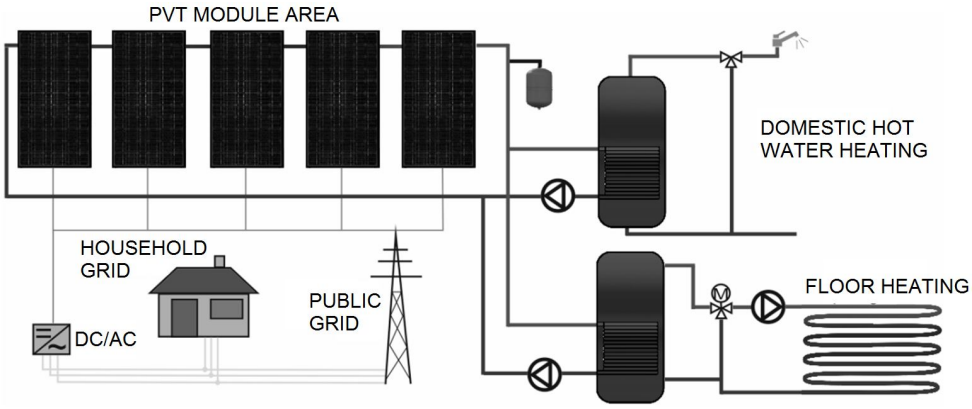

Fig. 3. Sample uses of PVT systems PVT [9]

Thanks to the installation which operates in such a way, the consumption of conventional energy needed to heat the building is decreased. At the same time, the efficiency of the PV system is increased by up to o 10%. Apart from generating thermal energy, the SolarDuct PV/T system also constitutes a complete support structure for the PV system which makes the investment more cost-effective [10].

4. THE PURPOSE OF INVESTING IN PVT

4.1. Advantages

The main advantage of using PVT, apart from the reduction of the operation temperature of the photovoltaic cells, is space savings. Instead of two separate installations, solar collectors for water heating, and a photovoltaic installation for electric energy generation, just one installation is fitted on the roof. Such a solution means that part of the investors with limited usable roof space do not have to choose between heat generation and electric energy generation.

Also the costs of such an installation are much lower than in the case of two traditional installations (solar collectors and photovoltaics). What is more, in the case of PVT with fully integrated construction, it is currently possible to obtain refinancing at the level of 45% for the modules including the hydraulic part of the installation.

Reduction of the costs connected with the installation, which results from the lower amount of work to be conducted on the surface of the building in comparison to the implementation of two systems is also worth noticing. This is applicable also to the fitting of PVT modules itself which, in most cases, have been designed to

match traditional PV installation clamps. Figure 4 presents a photo of a PVT module which differs from PV only with hydraulic clamps.

Fig. 4. Hybrid IPVT 300 Hybryda module [6]

PVT is also characterized by 50% higher efficiency than comparable conventional module. At the same time, manufacturers of photovoltaic thermal systems guarantee considerably longer service life of the photovoltaic cells thanks to the operation in lower temperatures [11].

4.2. Disadvantages

A disadvantage of this system is the mutual dependency of both systems. The most appropriate system operation time from the system efficiency point of view is summer time characterized by high insolation and high temperatures. It is then that both of the implemented systems operate at the highest efficiency level. On the one hand, it is possible to obtain low-temperature heat in the form of water heated to the temperature of 45°C, on the other hand, the operation of PV at lowered temperature in favorable insolation conditions. Thus, in order for the PVT modules to operate in an efficient way, it is necessary for the operation of the cell to be maintained at a low level, that is 35-45°C. It should be underlined that a PV system is relatively rarely heated to the temperature of more than 50°C.

Another disadvantage of PVT is the scale of the system. In the case of installations fitted on family houses, the photovoltaic component often takes up the area of over a dozen or a few dozen m^2, which means that a problem with receiving such a great amount of heat may arise in the summer period. In winter, on the other

hand, a hybrid PV/T system will generate considerably higher heat losses than a traditional collector installation due to the lack of a selective absorber and the appropriate amount of thermal insulation. This translates to lower temperatures of the heating medium obtained from them.

The thermal insulation of hybrid modules is also not as good as in the case of traditional solar collectors. Due to that fact, they are characterized by much higher heat loss levels and the temperature of the heating medium obtained from them is lower than in solar collectors.

5. CONCLUSION

Although in theory they combine the advantages of two systems whose popularity is constantly growing, in practice PVT systems seem to be a solution that has not been completely thought out. Although the manufacturers assure up to 300% higher efficiency in comparison to a traditional PV system, the increase in real operational conditions is a few dozen percent.

Undoubtedly, using such systems will be economically justifiable in the case of many investments, but their installation must be preceded with diligent technology and cost analysis.

REFERENCES

[1] Butera F.,Adhikari R. S.: "Hybrid Photovoltaic-Thermal Technology and Solar Cooling" http://www.pvdatabase.org 14:50 27.05.2013.
[2] Jastrzębska G.: „Ogniwa słoneczne", Wydawnictwa Komunikacji i Łączności, 2013.
[3] Mitică I., Andreea M.: "Energy efficiencies of a photovoltaic/thermal solar hybrid system", Annals of the University of Craiova, Electrical Engineering series, No. 32, 2008.
[4] Sarnik M. T.: "Podstawy fotowoltaiki", Oficyna Wydawnicza Politechniki Warszawskiej, 2008.
[5] Szymański B.: „Małe instalacje fotowoltaiczne", Geosystem, Kraków 2013.
[6] Budujemy dom Nr 5/2013.
[7] Globenergia Nr 2/2011.
[8] Newsweek Polska Nr 2/2008.
[9] http://www.sklep.thermika.com.pl/attachment.php?id_attachment=28 18:37 19.10.2013
[10] http://solarwall.com/pl/oferta/solarwall-pvt/solarduct-pvt.php 20:11 19.10.2013
[11] http://automaeko.sklepna5.pl/ 18:54 18.10.2013