THE ANALISYS OF THE PHOTOVOLTAIC AND ELECTRIC PARAMETERS OF A COOLING HYBRID SYSTEM. CASE STUDY

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Abstract - The paper presents the interdependence between photovoltaic and electric parameters of a solar thermoelectric cooler. It emphasises the importance of the solar radiation during two experiments made in the same day, in different weather conditions. Also, it is shown that while the photovoltaic power is directly dependent on the photovoltaic current intensity, the electric power varies along with the voltage. All these have great influence upon the battery – the main component responsible for the operation of the cooling hybrid system.

Keywords: solar, thermoelectric, solar radiation, battery, photovoltaic, electric, parameters.

1. INTRODUCTION

Nowadays, people are using different systems and equipment based on renewable energies. Systems that use renewable energies are continuously in a developing stage [1-7]. Life and materials are changing so quickly from day to day, that there is always the need of using something better than before.

Depending on their type and materials used, each act differently based on the most important parameters that characterize the renewable energies used. In the case of solar energy, the main factor is the solar radiation. But it is a very known fact that the solar radiation does not have the same distribution all over the globe, not even on the territory of a country (as solar and PV maps shows) [8]. Due to this, it is important to test equipment in different regions and climates and to analyse its operation. This will provide the needed information for a good development of the product.

In this way, a solar thermoelectric cooler was realized, similar to the one presented in papers [5-7]. The difference is done by the cooling thermoelectric modules TEC with a much greater refrigerating capacity. If the previous TEC modules had a refrigerating capacity of 80 W, the new ones present a value of 240 W of refrigerating capacity. This change reflected in the operation time. The same temperatures were reached in a much shorter time by using the second model than in the case of the first model of the solar thermoelectric cooler. The operation time being significantly shorter, two experiments could have been done in the same day.

The improved cooling hybrid system was tested in a temperate climate and the main goal of the experiments was to monitor and analyse the photovoltaic and electric parameters. Why? To see if the weather conditions translated into solar radiation and photovoltaic current intensity and power, respectively, provide the needed electricity for a good operation of the thermoelectric modules rated at a high maximum electric power of 90 W.

The paper presents the experimental PV and electric data registered during the two experiments made in the same day. The weather conditions were considerably different during the two case studies – sunshine during the first one and clouds on the second. This aspect clearly reflected on the solar radiation values.

Further on, the dependence of the photovoltaic parameters on the solar radiation is analysed. Also, it is presented the interdependence of the PV and electric parameters, with finality on the state of charge of the battery.

2. THE COOLING HYBRID SYSTEM

The designed cooling hybrid systems is made-up of two important components:

- the photovoltaic system;
- the thermoelectric part.

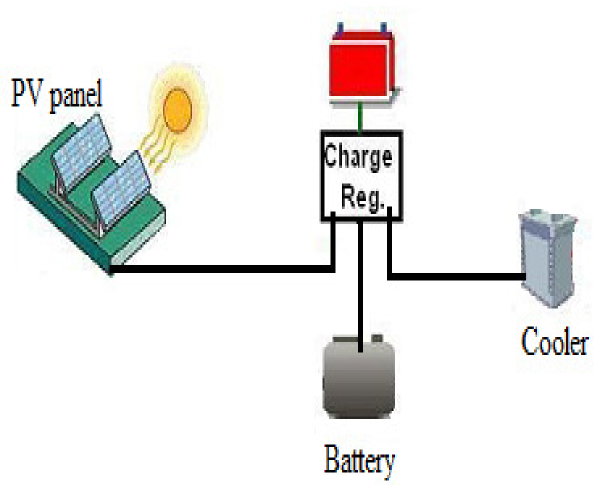


Fig. 1 - Schematic representation of the cooling hybrid system and its main components

The photovoltaic system consists of an amorphous Si

PV panel of 100 W connected to a charge controller. The a-Si photovoltaic panel was used due to its better performance on temperate climate (comparing to mono-Si and p-Si) [9]. The electric energy is stored into a deep cycling gel battery and further away delivered to the thermoelectric cooler.

The cooler is equipped with 4 cooling thermoelectric modules (TEC) of 60 W power of refrigeration. The maximum values of the DC current intensity I and of the voltage V are of I_{max} = 6 A, V_{max} = 15 V, according the specifications of the thermoelectric modules [10]. This leads to an electric power P of 90 W / module and an overall of 360 W / system. Because the photovoltaic panel is only of 100 W, the battery need to be charged one day completely before starting the experiments.

For the analysis of the photovoltaic and electric parameters (current, voltage, power and state of charge of the battery) to be done, the parameters had to be monitored. A datalogger included in the charge controller recorded the evolution of all the PV and electric parameters. The Phocos CXCOM software was used for the discharge of these data on the computer.

The solar radiation was measured with the PL-110SM Voltcraft pyranometer, with an accuracy of 5% [11]. Its measurement is important because the photovoltaic parameters depend directly on it, while the electric ones depend indirectly. In other words, the solar radiation is the main factor that influences and makes possible the operation of the entire cooling hybrid system.

3. THE ANALISYS OF THE PV AND ELECTRIC PARAMETERS

Exactly like it was mentioned in the previous section, the photovoltaic system ran alone on its first day of operation without any use of the electricity of the thermoelectric cooler. Fortunately, it was a shiny day and the battery fully charged. This fact allowed us to start the experiments the next day.

During the first experiment, the solar radiation registered good values with a mean of 557 W/m^2, except for the last two values of the solar radiation (I_{01}) - around 200 W/m^2 (fig. 2).

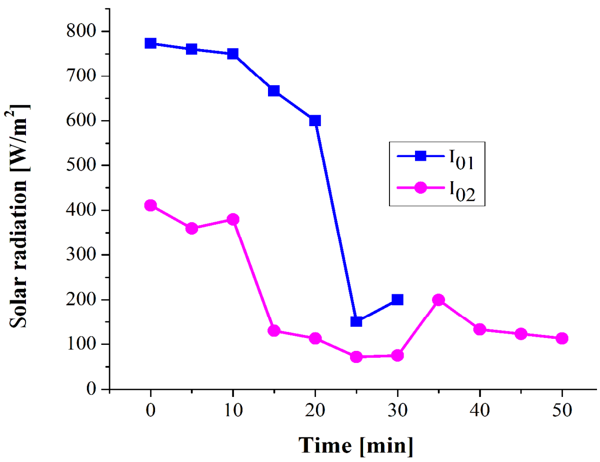


Fig. 2 - Variation of the solar radiation in time

Correlating the graphical representations for the first experiment in fig. 2 and 3, it can be easily seen that the state of charge of the battery highly decreased with the sudden decrease of the solar radiation. This is completed by the higher value of the electric power (P) versus the PV power (P_{pv}) – fig. 6.

The experiment lasted for 30 minutes. Why so short experiment? Because the main goal was to achieve and maintain for several minutes the refrigeration range of the thermoelectric cooler.

Considering all the mentioned aspects, the second experiment was conducted too, even if the state of the charge controller was quite low – 38% as it can be seen in fig. 3.

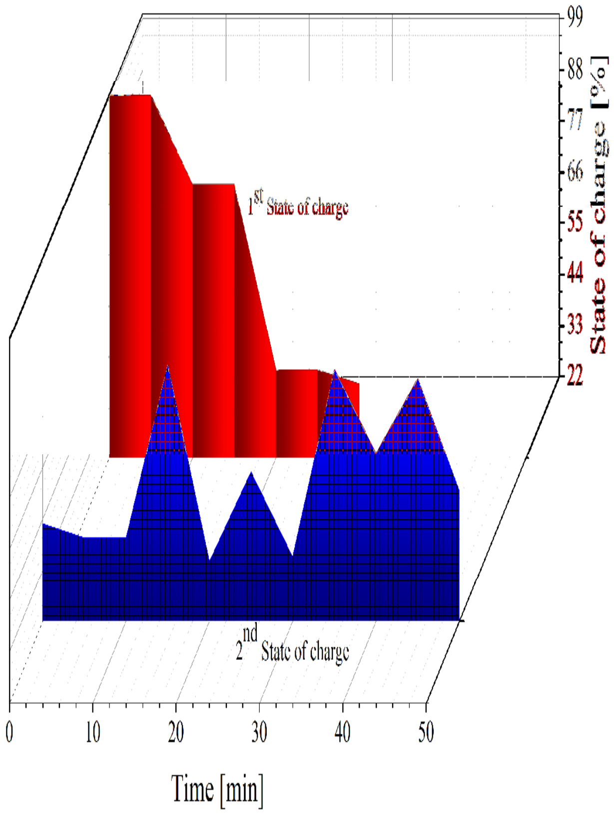


Fig. 3 - Variation of the battery state of charge during the two experiments

The two graphics from fig. 3 are extremely different. If the first representation presents constancies and linear decreasing of the battery state of charge, the second graph shows a very interesting curve with lots of ups and downs. This is explicable by the following aspects:

- the weather conditions changed radically during the second experiment, making the solar radiation (I_{02}) to drop to 72 W/m^2 and then increase again to 200 W/m^2 (fig. 2);
- the decrease of the voltage in the battery led to an increase of the state of charge;
- in the last part of the experiment, the temperature of the cooler remained almost constant, so the use of the DC current provided by the battery was diminished significantly.

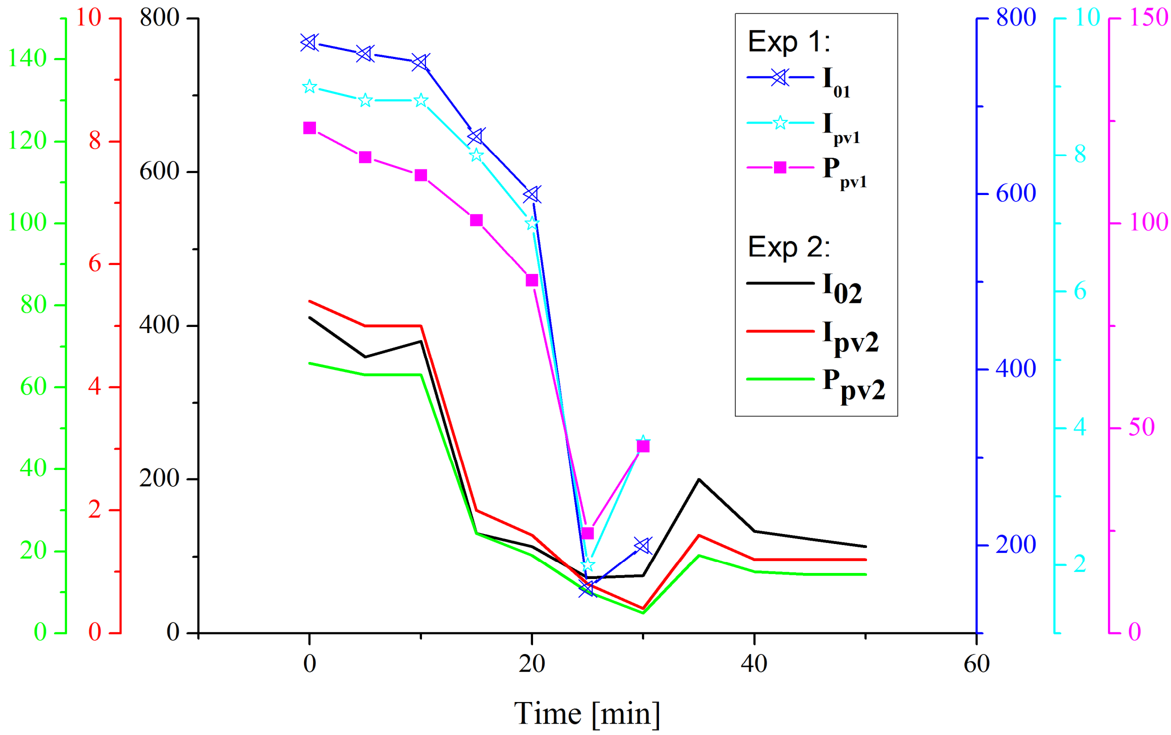
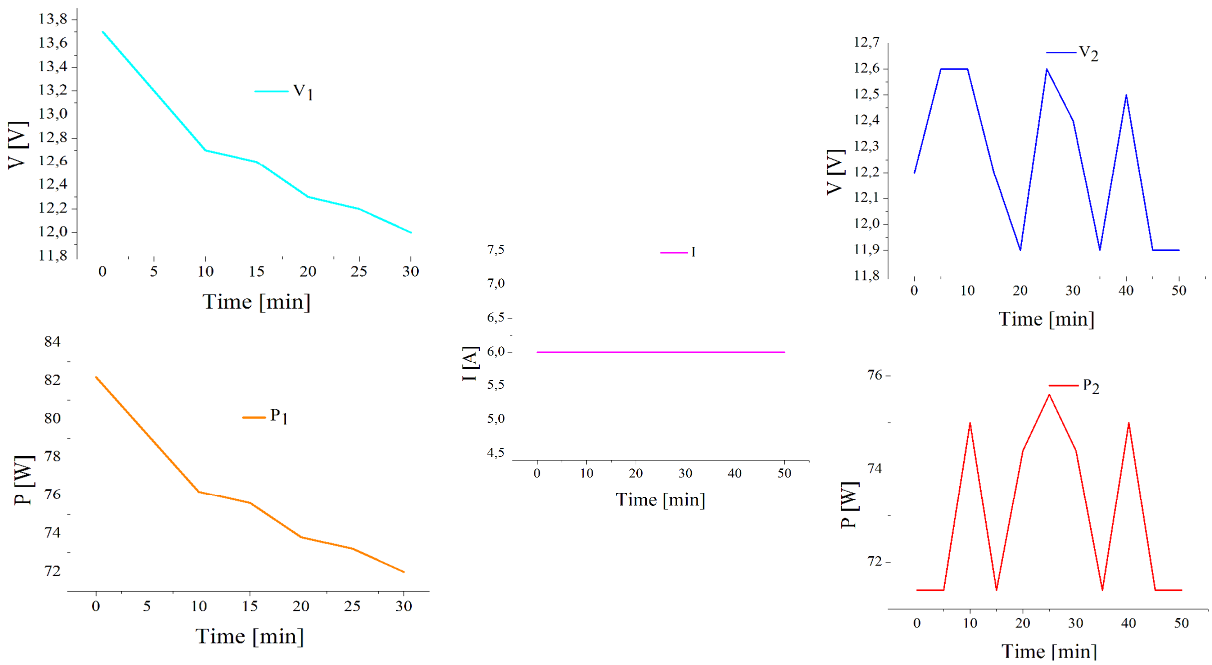


Fig. 4 - Comparison between the PV parameters



1. First experiment

2. Second experiment

Fig. 5 - The evolution of the electric parameters – current intensity *I*, voltage *V* and power *P*

Because the photovoltaic current intensity (I_{pv}) and power are directly dependent on solar radiation, the values monitored during the second experiment are significantly lower than the first ones, as fig. 4 describes it.

The PV power given by relation:

$$P_{pv} = I_{pv} * V \qquad (1)$$

confirms that the variation curve of the photovoltaic power is directly dependent by the PV current intensity delivered by the photovoltaic panel.

Not the same thing can be said by the variation of the electric power depending on the DC current intensity and the voltage. While the current intensity remained constant along the entire operation of the cooling hybrid system (I_{pv} reached the maximum rated value of 6 A), the voltage was below 15 V (rated by the producer of the thermoelectric modules). Starting from a value of 13.7 V, the voltage dropped to 11.9 V in the end. Therefore, the electric power has almost the same trend of the curve like the voltage (almost identically in the case of the first measurements) – fig. 5. This fact is confirmed even by the equations of the variation - a 3rd degree polynomial, graphically described in fig. 6 and fig. 7:

$$F(x) = a_3x^3 + a_2x^2 + a_1x + a_0 \qquad (2)$$

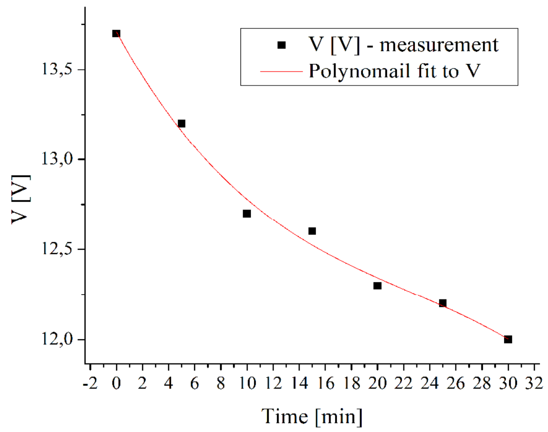


Fig. 6 - Equation of variation vs data for voltage

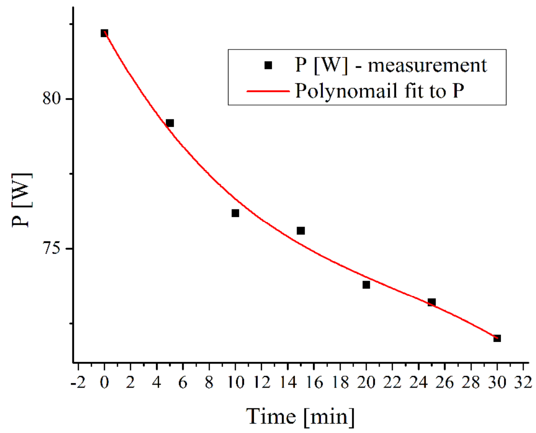


Fig. 7 - Equation of variation vs data for power

Another analysis is to be done between the photovoltaic and electric power. There are very clear from fig. 8 the differences that appeared during the use of the cooling hybrid system between the two types of power. The decrease of the solar radiation and its lowest values in the second part of the experiments is highly reflected in the variation of the P_{pv1} and P_{pv2} – the photovoltaic powers registered during the first, respectively the second case.

The variation range of the electric power is higher in comparison with the one of the PV power, referring to all period of time. The photovoltaic power registered an average of 51 W along the entire experiments, while the mean of the electric power was of 74 W.

This important difference is reflected especially in the second case study, when the PV power had a mean of only 28 W and the electric power P stayed around 72 W. This is a consequence of the constant value of the DC current intensity I and of the low (even extremely low) decrease of the voltage V during the experiments – a decrease of 1.7 V in the first case and of 0.7 V in the second.

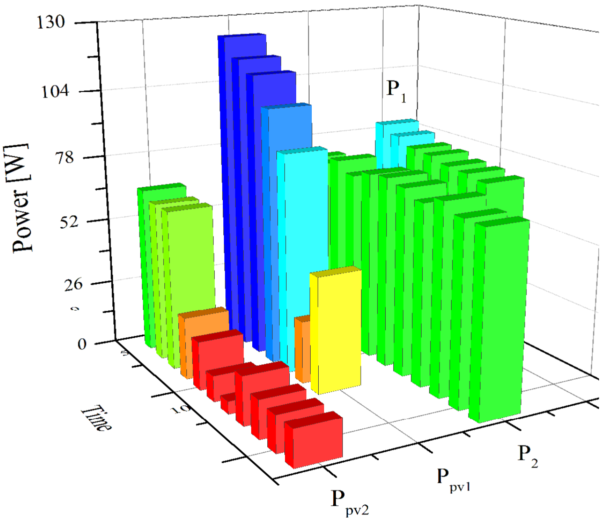


Fig. 8 - Analysis of the photovoltaic and electric power

These confirm once again the biggest discharge of the load battery – from 100% at the beginning to 35-40% along the measurements.

4. CONCLUSION

The analysis of data recorded in these case studies emphasized the need of a reasonable to high mean value of the solar radiation for a better operation of the solar thermoelectric cooler. This ensures a good state of charge of the battery.

The photovoltaic parameters – current intensity and power – are directly dependent on the solar radiation. These PV parameters have a very similar variation trend like solar radiation.

The solar radiation indirectly influences the state of charge of the battery, too. Both absence and low values of solar radiation during the operation of the cooling hybrid system are equivalent to a high state of discharge and the impossibility of still working the cooler. If the weather conditions are good (in a shiny day or with not many clouds), then the battery is continuously charged and the cooling system can work properly.

If the battery allows it, the DC current intensity needed for the operation of the thermoelectric modules is at its maximum rated value. In this case, the voltage is the one varying. Once with the variation of the voltage, varies the electric power. And their variation trend is almost the same, especially at high values of the voltage.

REFERENCES

[1]. Ghafoor, A., Munir, A. – Worldwide overview of solar thermal cooling technologies, in Renewable and Sustainable Energy Reviews, vol. 43, 2015, pg. 763-774

[2]. D'Antoni, M., Romeli, D., Fedrizzi R. – A model for the performance assessment of hybrid coolers by means of transient numerical simulation, in Applied Energy, vol. 181, 2016, pg. 477-494

[3]. He, W., Zhou, J., Hou, J., Chen, C., Ji, J. – Theoretical and experimental investigation on a thermoelectric cooling and heating system driven by solar, in Applied Energy, 2013, pg. 89-97

[4]. Abdul-Wahab, S.A., Elkamel, A. et al. – Design and experimental investigation of portable solar thermoelectric refrigerator, in Renewable Energy, vol. 34, 2009, pg. 30-34

[5]. Mare, R. – The behaviour of a solar thermo-electric refrigerator in the case of cooling milk, in Mathematical Modeling in Civil Engineering, vol. 8, no.4, 2012, pg. 125-132

[6]. Mare, R.; Rus, T. – The analysis of temperature variation and efficiency of an experimental thermo-electric – photovoltaic system when cooling carrots, in Bulletin of the Transilvania University of Braşov, Series I, vol 6, 2013, pg. 261-266

[7]. Mare, R., Hădărean, A. – The idling of a cooling hybrid system in winter time in Cluj County, in Bulletin of the Transilvania University of Braşov. Series I: Engineering Sciences, vol 8, no. 57, 2015, pg. 371-376

[8]. *** European Commission, Institute for Environment and Sustainability – Solar radiation and PV maps - Europe (Africa), PVGIS 2001-2007, Retrieved on April 2017, Available online: http://re.jrc.ec.europa.eu/pvgis/countries/countries-europe.htm

[9]. Carr, A.J., Pryor, T.L. – A comparison of the performance of different PV module types in temperate climates, in Solar Energy, vol. 76, 2004, pg. 285-294

[10]. *** Specifications of the Cooling Thermoelectric Modules TEC1-12706

[11]. *** Specifications of the Voltcraft PL-110SM Solar Raddiation Measuring Instrument