https://dx.doi.org/10.22161/ijaers.75.45 ISSN: 2349-6495(P) | 2456-1908(O)

Influence of the Operating Temperature and the Solar Irradiation in a Photovoltaic Panel: An Experimental Analysis

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Abstract— *The search for real solutions that meet the growing demand for energy in the global scenario has been the subject of studies around the world for the scientific community. Renewable sources and technologies are investigated for the replacement of fossil fuels, non-renewable and with high potential for environmental degradation energies. Renewable energy that highlights in the area of sustainability is solar energy, due to environmental, social and abundance aspects. Despite obtaining electricity directly from the solar incident in a photovoltaic system, approximately 80% to 90% of the incident energy is converted into heat. This heat results in an increase in the operating temperature of the photovoltaic panel cells, causing a 0.45% decrease in panel yield for each degree Celsius [°C] added from the standard test conditions: 25 °C, 1 kW/m^2 and 1.5 kg of air. In the present paper, an experimental analysis of the influence of the operating temperature and the solar irradiation in the voltage generated by a photovoltaic panel was presented, in order to understand the importance of the control of the operating temperature of a photovoltaic panel. The results prove that the generated voltage is directly connected to the operating temperature of the photovoltaic panel. A rise in solar irradiation elevates the produced voltage. However, the increment of the operating temperature of the panel results in a gradual loss of voltage produced.*

Keywords— ***operating temperature, photovoltaic panel, solar energy, voltage.***

I. INTRODUCTION

The demand for energy has been growing every year. It is estimated that world energy consumption will grow by more than 30% by 2040 considering all sectors that need energy, such as industrial, agricultural, medical, transportation and domestic [1].

The search for real solutions that supply the growing demand for energy on the global stage has been the subject of studies around the world for the scientific community. Renewable sources and technologies are investigated to replace fossil fuels, non-renewable and with high potential for environmental degradation energies [2].

One form of renewable energy that highlights in the area of sustainability worldwide is solar energy, due to environmental, social and abundance aspects. In 2014, solar energy counted out approximately 30% of the new energy capacity from renewable sources worldwide [3].

The cost of solar systems still high, but this investment has become more viable in recent years due to rising fossil fuel costs and the evolution of solar technology. Data from Ren21 [4] show that photovoltaic energy already reaches 505GW of total global capacity, which a decade earlier was 15GW.

Brazil is one of the largest countries in the world in terms of territory and, according to the Brazilian Atlas of Solar Energy 2017, due to its geographical position, it has a high rate of solar radiation. Thus, photovoltaic electricity generation has great potential in Brazil throughout the year [5]. The intensity of the sun’s rays depends on the geographical latitude of the area and the season (inclination of the earth's axis). Figure 1 shows the global annual average solar radiation in the Brazilian territory, respectively.

Solar energy can be easily converted to another form of energy basically by two systems, thermal and photovoltaic. The thermal system transforms solar energy into heat.

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Already the photovoltaic system converts the solar irradiation in electricity [6]. Photovoltaic systems transform the incidence of sunlight on the surface of Silicon into electrical energy. Electrons are excited and generate a d.d.p. in the panel by the photovoltaic effect.

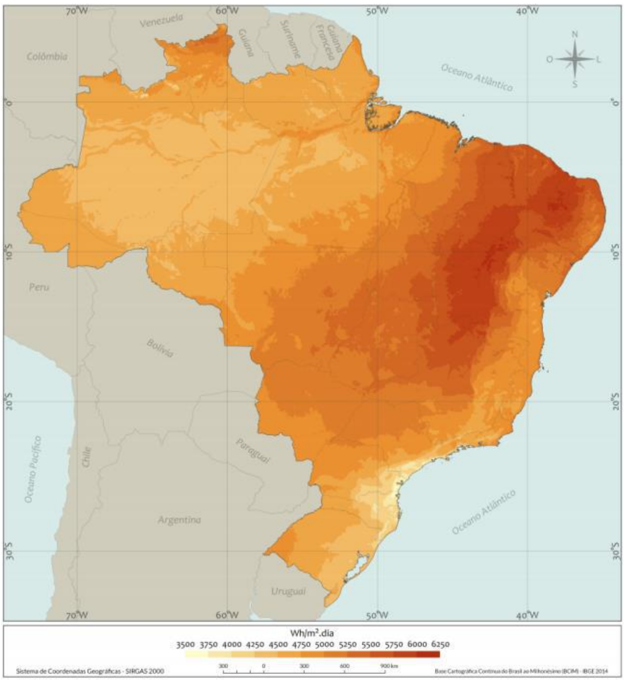

Fig. 1: Global solar radiation in Brazil, the annual average [5]

Although electricity is obtained directly from sunlight in a photovoltaic system, approximately 80% to 90% of the incident energy is converted into heat. This heat results in the increase of the cell operating temperature of the photovoltaic panel, promoting a yield reduction of 0.45% for each Celsius degree [°C] added from standard test conditions: 25°C, 1 kW/m^2 and 1.5 kg of air [7]. Panel performance drop is due to a significant reduction in the voltage produced with increasing temperature. At the same time, its current undergoes a small increase, but almost negligible, which does not compensate for the loss caused by the decrease in voltage, reducing the power produced by the system.

In this context, the present work analyzed experimentally the influence of the operating temperature and solar radiation on the voltage generated by a photovoltaic panel. Therefore, the importance of controlling the operating temperature of a photovoltaic panel can be understood.

II. METHODOLOGY

The experimental apparatus utilized for tests were divided into two sections, an external and an internal. The external sector, exposed to irradiation, was composed of a photovoltaic panel with polycrystalline cells (*China Solar LTD*™ *Kaxidy KS-P*10*W*), a pyranometer (*Kipp & Zonen*™) and a table with tilt adjustment, as shown Fig. 2. The characteristics of the photovoltaic panel are presented in Table 1.

Fig. 2: External experimental apparatus

Table.1: Characteristics of China Solar LTD™ *Kaxidy KS-P*10*W photovoltaic panel*

Parameters	Panel
Power	10 W
Open Circuit Voltage	21.6 V
Open Circuit Current	630 mA
Solar Cell Type	Polycrystalline Silicon
Nominal Operating Temperature	45°C ± 2°C
Temperature Coefficient in Open Voltage	(-0.34%/°C ± 0.01)
Temperature Coefficient in Short-circuit Current	(0.045%/°C ± 0.01)
Operating Temperature	- 40°C up 85°C

Figure 3 shows the experimental apparatus used indoor that was composed of a data logger (*Agilent*™ 34970A with 20 channels) and a laptop (*Dell*™), so the electronic equipment was protected from solar radiation.

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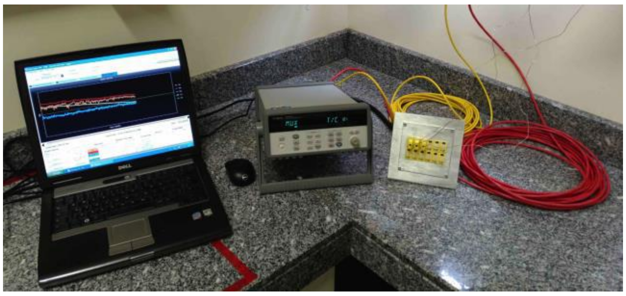

Fig. 3: Indoor experimental apparatus

In the evaluation of the thermal performance of the photovoltaic panel, three K-Type *Omega Engineering*[TM] thermocouples were used. A temperature sensor was attached to the upper surface of the panel and one to the lower surface. Also, a thermocouple evaluated of the ambient temperature.

The photovoltaic panel was tested experimentally at an inclination of 25°, which is the city latitude of the test realization (Ponta Grossa/PR: 25° 05' 42" South).

III. RESULTS AND DISCUSSION

The results present the experimental behavior of a 10W photovoltaic panel. The test was realized during 6 (six) hours, in order to use the maximum solar radiation. Data were acquired every 10 (ten) seconds by the data acquisition system and recorded on the computer using the software *Agilent*[TM] *Benchlink Data Logger* 3. Subsequently, the data were processed to assess the performance.

The behavior of solar irradiation as a function of exposure time is shown in Fig. 4. As soon as sunlight directly reaches the photovoltaic panel, irradiation rises dramatically.

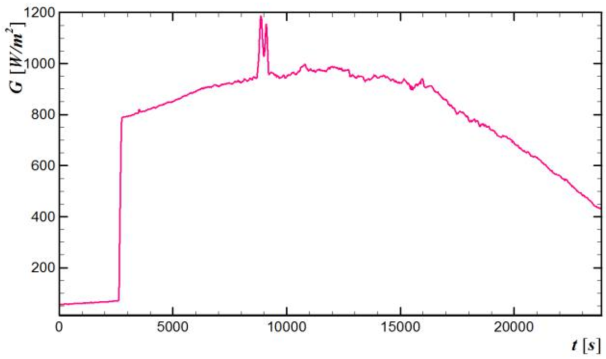

Fig. 4: Solar irradiation during the test

The operating temperature in the photovoltaic panel and the voltage generated by the panel over the panel as a function of time, are shown in Fig. 5 and Fig. 6, respectively.

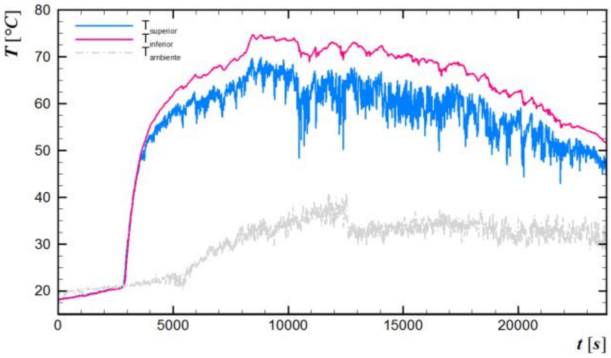

Fig. 5: Operating temperature of photovoltaic panel versus time.

The voltage increases with rising solar radiation and gradually decreases with the increasing operating temperature of the photovoltaic panel. As soon as the panel was exposed to solar radiation, the maximum voltage value in an open circuit was reached, but as the temperature of the panel increased, the value of voltage produced by the panel decreased. In this way, a cooling system for the photovoltaic panel can reduce its operating temperature, improving the performance and increasing the production of electrical energy from solar energy.

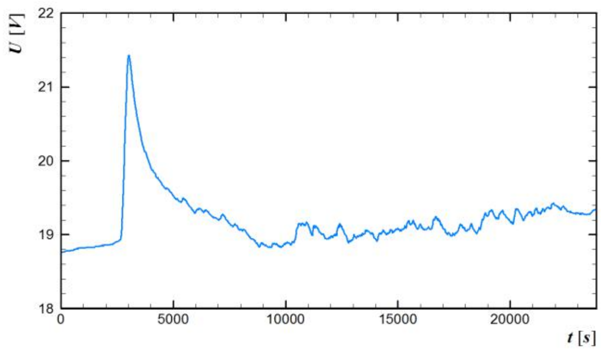

Fig. 6: Produced voltage versus time

IV. CONCLUSION

In the present work, the influence of the operating temperature and the solar irradiation in the voltage produced by a photovoltaic panel were evaluated experimentally. The purpose of this study is to understand the importance of temperature control for photovoltaic panels. The results prove that the generated voltage is directly connected to the operating temperature of the photovoltaic panel. A rise in solar irradiation elevates the produced voltage. However, the increment of the operating temperature of the panel results in a gradual loss of voltage produced.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to the CAPES for granting a master's scholarship. Moreover, acknowledgments are provided to the CNPq, the PROPPG/UTFPR, the DIRPPG/UTFPR, the PPGEM/ UTFPR/Ponta Grossa, and the DAMEC/UTFPR/Ponta Grossa for their support.

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