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THERMAL EFFICIENCY OF PHOTOVOLTAIC SYSTEM IN UNIVERSITY IN BRASÍLIA

Karoline Dayane Santana Cruz
Eugenia Cornils Monteiro da Silva
Luciano Henrique Duque
Antonio Cesar Pinho Brasil Junior
University Center of Brasília – UniCEUB, Campus da Asa Norte: SEPN 707/907 - Campus Universitário. CEP: 70790-075
karoline.dayane@sempreceub.com
eugeniacornils@yahoo.com.br
luciano.duque@ceub.edu.br
brasiljr@unb.br

Abstract. *This paper presents the analysis of the performance of the photovoltaic system of the University Center of Brasília (UniCEUB). In order to carry out this study, it was necessary to use thermographic camera and pyranometer equipment. The analyzes were carried out from the simplification of the formula developed by Jones and Underwood, which considers the losses by convection and conduction in the plates. After completing the calculations, graphs were performed that measured the performance of the power in relation to the temperature of the module, the power in relation to the ambient temperature, of the irradiation in relation to the power generated and finally a comparison was made between the irradiation calculated through the Jones' formula and the irradiation actually measured on the day. And the efficiency of the data sheet of the panel was compared with the efficiency calculated. This will allow to analyze where system losses.*
Keywords: Photovoltaic, Irradiation, Temperature, Power.

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1. INTRODUCTION

Brazil is one of the South Americas' country with the best development about renewable energy. In 70's was built the first photovoltaic module industry due the oil crisis. Recently, Brazil's between the countries with the best rates of solar radiation, besides the lack of rules is an obstacle for the technology's progress. In the end of 90's the global photovoltaic market multiplied four times due to the technical advances and the support politic (GELLER,2003).

The energetic efficiency can be defined by the capacity to decrease the energy consume in an efficient way which has the lowest rate of waste (GELLER, 2003). A better energetic efficiency diminishes the energy development to increase, decrease the investment demand and improves the energy services to the Society. The right use of the energy has become extremely important due its great demand and limited sources; thus, it has increased the actions for the improvement of the efficiency (VILLALVA, 2015). Yet the best photovoltaic cells performance can influence in several factors, as: the environment temperature and the solar irradiation. One of the principal's factors that affects right the energy production by the photovoltaic plates can be the overheat of the plates, shading and the irradiation temperature on the place. With this, it has as a tool to analyze the temperature, the thermography, which consists at the technical measurement of superficial temperature distribution from the object in real time.

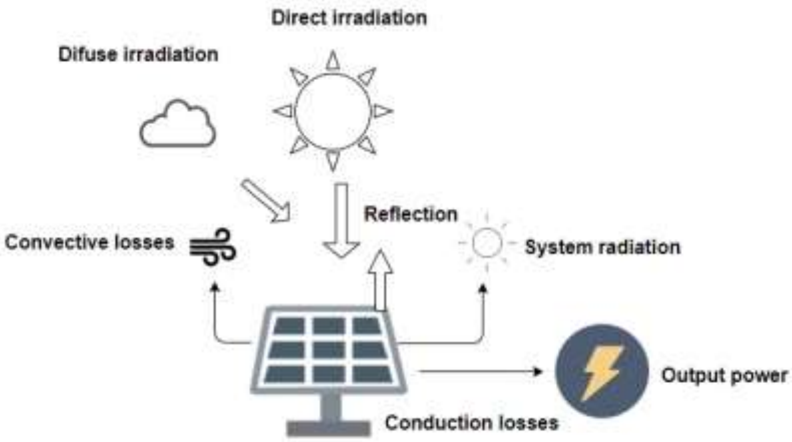

Figure 1. Energy Balance of Photovoltaic System

Figure 1 is an illustration of the losses that occur in the photovoltaic module. Convection encompasses two mechanisms of energy transfer, one due to random molecular motion, and the other through global or macroscopic fluid movement. This fluid movement is associated with the fact that at any given moment a large number of molecules are moving collectively or as an aggregate. Such movement, in the presence of a temperature gradient, contributes to heat transfer (INCROPERA et al., 2007). Newton's law of cooling expresses the exchange of convective energy from a surface to the surrounding fluid as being proportional to the global temperature difference between the surface and the fluid. For a photovoltaic module, Eq. (1) expresses the total convective energy exchange of a module surface.

$$Qconv = -hc.A\ .(Tmod - Tamb) \tag{1}$$

The temperature distribution on the surface of the modules to cause different impacts on the flow this phenomenon therefore the need to perform various measurements on the surface of the modules and calculate an average temperature (WU et al., 2017). It's a non-invasive method that detects, visualize and record different levels of temperature distribution by the object surface over a thermic camera (thermal imager) (CARAMALHO, 2012). The impact of temperature on the generation efficiency of the photovoltaic module caused the correlations between the dimensionless numbers to be analyzed again in several works. In this analysis it was suggested the best correlations for each position situation of the photovoltaic system and flow regime that defined the flow characteristics (BOJAN et al., 2017).

The photovoltaic production is not a production which remains constant, during the day occurs potency variations that can be justified by the local irradiation in a certain moment. One tool to analyze the irradiation is the pyranometer, it is a radiation sensor that has the function to measure the global radiation on a flat view and contains a high measure precision. At the photovoltaics pane is required to be maintained a appropriate temperature and irradiation to obtain the best efficiency system. The overheating can damage the panel and spoil the performance. And it is a known fact that the tests carried out on the panels and results described in the manuals do not have an adaptation to local environmental conditions. A divergence between the identified efficiency values may occur.

Thus, this research focus on irradiation data analyze, potency and temperature in photovoltaic power plants on Block 8 on the Center of the Brasilia's University – UniCEUB, located in Asa Norte of Distrito Federal. To such place, it is necessary to follow the solar irradiation incidence, the temperature of the modules is the potency on the inverters at the power plant of the Block 8, lastly it is pointed out the losses and the possible mistakes occurred by the weather and to propose solution to improve de system's efficiency.

2. MATERIALS AND METHODS

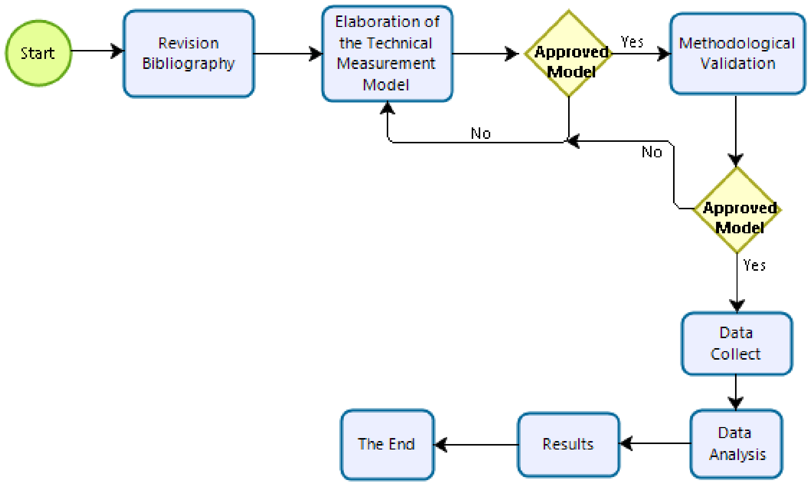

Figure 2. Methodology Flowchart.

For the elaboration of this article a bibliographical review was initiated, which contained all pertinent subjects to the chosen theme. After the bibliographic review was completed, the elaboration of the technical model began, after its approval, it resulted in a way to collect the data simultaneously without losses. Subsequently, the data collected underwent a methodological validation, which analyzed the data collected with existing equations, after the approval of the data obtained, data collection began and finally the results that will be presented in this work were generated. Shown in the Fig. 2.

The measurement was realized weekly on Thursdays during a five weeks' period and intercalating the measure each 15 minutes.

The photovoltaic systems were supported on the slope of the roof structure, the inclination in both sides was 3,3°. This inclination has impact on radiation exposure and thermal exchange, usually for best performance the systems are positioned facing the geographical north on the slope equal to local latitude.

Figure 3. The tilt meter used to measure the angle of inclination of the panel

To do the metering, it was used the tools: Thermographic Camera Flir i3, Figure 4 and a Pyranometer Kipp & Zonen, Fig. 5 of second class. It's realized 5 measurements only in the days that wasn't raining or cloudy.

Figure 4. Thermographic Camera Flir i3

Figure 5. Pyranometer Kipp & Zonen

Figure 6. The figure A represents the group of panels on the right side; the inclination of this group was 3.3° with the horizontal. Figure B represents the panels on the left side with the slope of 3.3°

In the instant the metering has started, it was collected the irradiation and, simultaneously, the potency at the inverter with the help of a monitor, during this period of the research has been collected 20 temperatures on the plates with the thermographic camera in random. On a purpose to calculate, it has been used average of the temperature of the plates. Due to the period of the measurement of the potency average can be much bigger than the period of the thermal response, thus, based on the theoretical temperature description of the written models from Jones (2001), it was used an expression that relates temperature of the model on the irradiation terms and the environment temperature. Considering 3 types of heat transfer: conduction, convection, irradiation and the potency produced by the system too, it expressed on the Eq. (1), the calculation of the photovoltaic models. The details of the contributions are adapted on this research.

$$Irr = Qconv + Qi + Pot \tag{1}$$

To calculate the efficiency was identified equations presented in the article developed by Skoplaki (2008), which presents a review of the correlations of efficiencies. For the development of this work was chosen the formula developed by Evans (1981), which relates a reference of efficiency and temperature expressed in Eq. (2).

$$\eta_T = \eta_{ref} [1 - \beta_{ref} (T - T_{ref})] \quad (2)$$

Another way to estimate efficiency is by using Eq. (3) which relates power to the global radiation incident in the total area of the panels. That form should be assessed since there are other losses such as, for example, that of the inverter that must be assessed.

$$\eta_T = Pot/G.A \quad (3)$$

3. OUTCOME

The photovoltaic cells performance is related straight in the radiation and the temperature of the models. The next graphics confirm the theory that the temperature of the modules and the irradiation influence right on the potency. Comparing the theoretical model to the module's temperature, according to Jones (2001) as in the Eq. (1), with the reality it was possible to find the irradiation varies producing a variation on the module's temperature as well and eventually on the potency. It can be proven that the radiation is directly proportionally to the potency, according to the Fig. 1.

The relation between the potency variants and temperatures is not too strong but the points should be the next of a line. Then, the value to analyze the others variants which has impact on the potency.

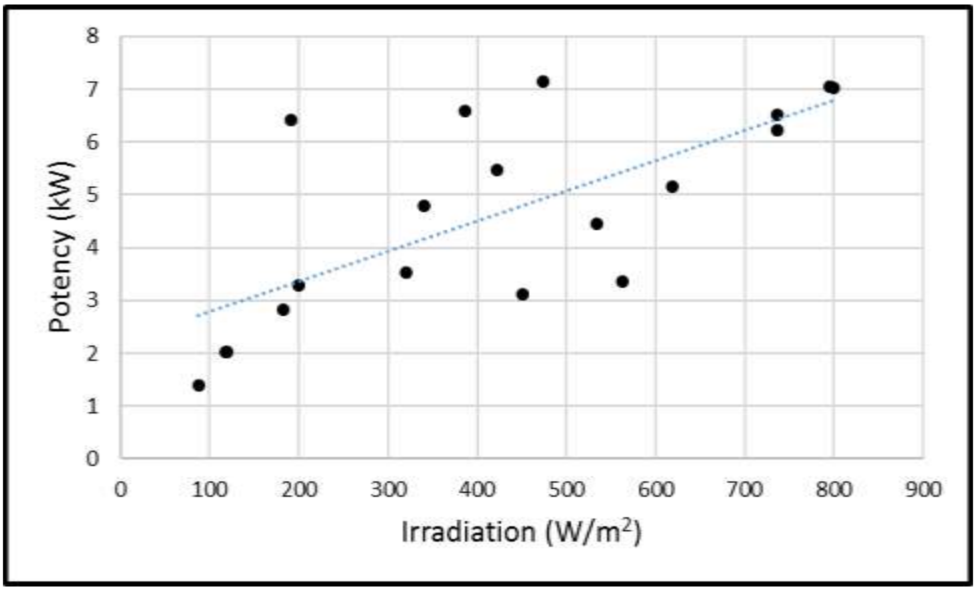

Figure 7. Graphic relating the Irradiation (W/m²) from the instant of the Potency (kW)

Analogous to the relation of Irradiation and Power, the correlation between the Irradiation and the Temperature of the module is shown. In which, with the increase of the Irradiation there is a gradual increase of the temperature of the module, shown in Fig. 2 below.

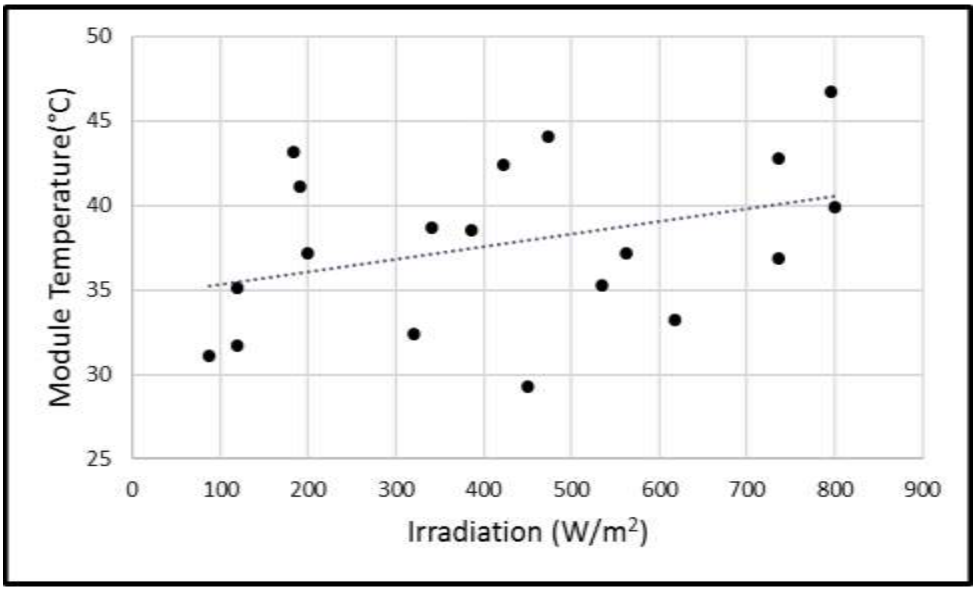

Figure 8. Graphic relating the Irradiation (W/m²) by module temperature (°C)

After the use Evans' (1981) efficiency formula it was possible to confirm that the temperature of the module is inversely proportional to the producing efficiency. Once the temperature increased, there was a fall of the efficiency. The panels used on the research are from the brand "Canadian Solar", model CS6P-260/ 265P which has the max potency of 265 W and an efficiency of 16,47% in the manual, watching that the minimum efficiency obtained at the period of the research was 6,9%.

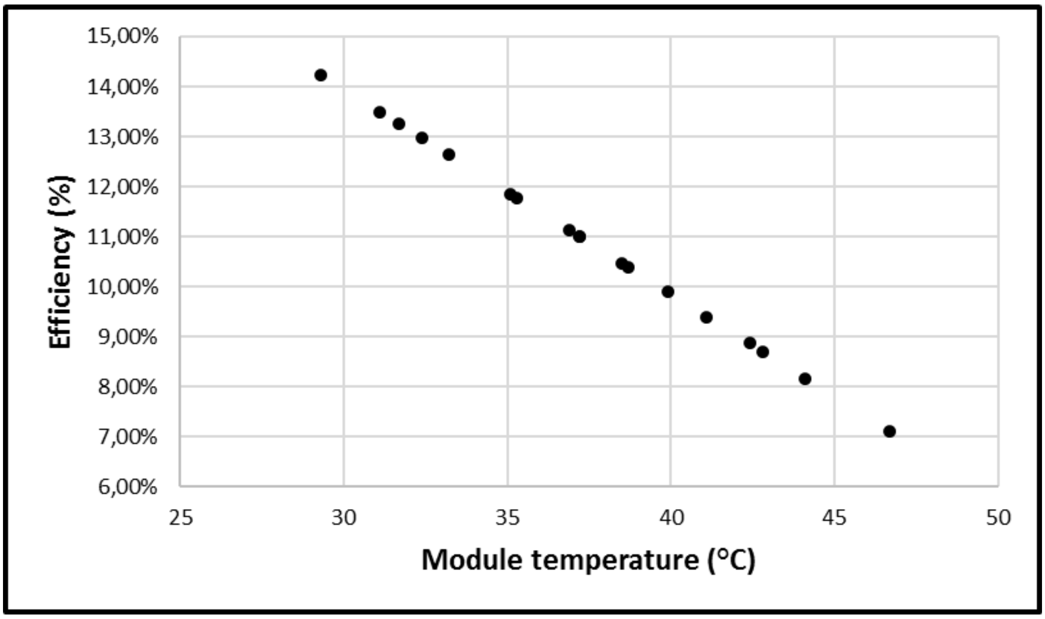

Figure 9. Graphic relating the Temperature of Module (°C) and the producing Efficiency (%)

In Fig. 10, the corrected efficiency for the operating temperature of the module using the Eq. (2) is described in relation to the temperature increase. However, when the efficiency is calculated from the generated power divided by the multiplication of the irradiance by the area, we do not get such a clear correlation. This can be attributed to the impact of other variable, like as excessive elevation of the module temperature, system losses not considered in the system or even a lack of adequacy of the manual parameters for regional environmental conditions. Showing that this way of calculating efficiency for the system is not appropriate.

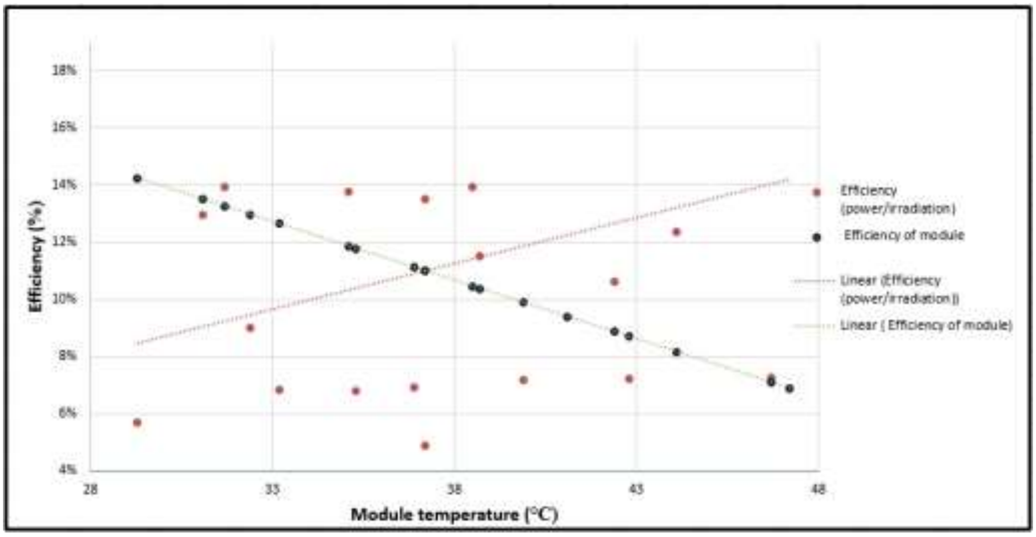

Figure 10. Graphic relating the efficiency of data Sheet of Module (°C) and the efficiency considering the relations between potency per irradiation in system area (%)

4. CONCLUSIONS

In this paper, weekly data of irradiation, temperature of the module of photovoltaic plant of Block 8 in the University Center of Brasília - UniCEUB, were analyzed, directly related to generation efficiency. Using an adaptation of the method developed by Jones and Underwood, to calculate the irradiance, considering the power of the system, heat transfer by conduction and convection. The simplified Evans method was also used to calculate the efficiency of the System.

Measurements began on August 30, were finalized on October 4, using equipment such as pyranometer and thermal imager. As expected, a relationship was found between the level of solar irradiance and the thermal response of the system through its power, in which it was possible to verify that, according to the increase of the solar irradiation, an increase of the generated power occurred simultaneously. Confirming what concerns the characteristics that affect the photovoltaic system, explaining that the performance is directly linked to solar irradiance and temperature. Similarly, the efficiency is also directly related to the temperature of the photovoltaic module, since the higher the temperature the lower its efficiency.

After the end of the analysis it can be seen that the UniCEUB system is operating in optimum conditions. The panel can provide an efficiency of up to 16.47%, on the days of measurements the maximum efficiency value was 14.24% and minimum of 5.68%. However, a greater gain would be possible if the photovoltaic modules were positioned to the geographic north and with correct angulation, that would be of 15 °, being able to vary between 5 ° and 25 °.

This low efficiency can be attributed to varied factors that show that the system needs improvement in its configuration to increase its power conversion capacity.

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