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DETECTION OF HOT SPOTS BY MEANS OF THERMOGRAPHIC CAMERAS IN SOLAR PANELS AT THE TECHNICAL UNIVERSITY OF MANABÍ

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Summary

Hot spots in photovoltaic systems are problems that cause a decrease in energy generation. Being able to detect them in time helps to carry out maintenance that improves generation efficiency. The objective of the investigation was to detect the hot spots using a thermographic camera in the photovoltaic power plant of
3.4 kW located in the Faculty of Sciences, Mathematics, Physics and Chemistry using a thermographic camera, the Smart View software was used to perform the thermographic inspection and analysis of the same data. It was obtained that there were no hot spots, only temperature difference in the module due to dirt, so maintenance is proposed through periodic cleaning of the solar panels.

Keywords: Hot spots, breakdowns, thermography, solar panels, inspection

Introduction

Infrared radiation was discovered in the 19th century, its first measurement achievements being in 1920, this was used in the Second World War for military purposes, to detect the enemy at night and guide missiles through infrared radiation, once finished war the first thermal imaging camera for personal and commercial use was launched on the market, it should be noted that the first cameras were large, heavy and difficult to handle, however with the advancement of technology the first cameras appeared in the 80s comfortable and manageable (ORGLMEISTER, 2023).

The thermographic camera helps to analyze the radiation emitted by objects, this has allowed evaluating the advantages and limitations of the infrared thermography test for the inspection of reinforced concrete bridges (Rocha &Povoas, 2017).

The energy produced by photovoltaic devices plays a significant role in the electrical system, research related to improving the performance of the panels has been developed. The thermographic method allows greater detection of hot spots that can affect the performance of solar panels. Infrared thermography has become a common tool for preventive and preventative maintenance of solar panels, the use of this technology helps to obtain information about the state of the panel plant, to know the possible errors of the thermographic analysis and the necessary conditions for carry it out (Navarro, 2022).
At the University of Seville, a study was carried out on the temperature problems that influence the efficiency and temperature of photovoltaic panels, thus being able to analyze their production and efficiency of solar panels.
With thermography, any type of anomaly in the panels can be detected, such as the presence of broken cells and cracks between their junctions (Ramos, 2022).

Solar panels can often be subjected to mechanical damage or carelessness, which can cause a cell to break, also due to the accumulation of dirt due to poor maintenance, this causes internal stress effects in the cells, which result in The result is the appearance of hot spots, because of this an increase in electrons is created that manifests itself in the form of heat, in this sense they can have a temperature greater than 50 ° C compared to cells in good condition, for this reason reason can cause irreversible damage to the entire panel (energetic C., 2020).

The use of the thermographic camera to detect hot spots in a photovoltaic plant, allows to see images in a concise way, showing the hot spot all around, with this through the Smart View software (Fluke, 2023), this allows to perform a analysis of the conditions in which the affected cell is located and issue a clear report on the status of the panel (aliter.com).

In the Faculty of Physical and Chemical Mathematical Sciences of the Technical University of Manabí, projects related to sustainable development are being developed to promote the use of renewable energy sources (FRE), for this reason a small photovoltaic plant of 3, 4 kWp, which provides energy in the form of distributed generation to building 1, of the faculty, thereby demonstrating its feasibility.

Different investigations have been carried out at this plant that have demonstrated its feasibility for research, for example, the influence of temperature on generation (Epeni, Rodríguez, Loor, Vázquez, &Nuñez, 2023), taking into account that it can be used the installation based on the investigation, a study was carried out to evaluate the hot spots in the solar panels using the thermal imaging camera.

Photovoltaic solar energy is a renewable energy that is created after the direct transformation of radiation and light from the sun into electricity. This transformation is possible thanks to devices called photovoltaic panels, which make solar radiation hit the photovoltaic cells (Claudio, 2019).

In order for the photovoltaic system to have its maximum generation, the photovoltaic panels must be maintained, because there are environmental parameters that can affect their generation, such as dirt (León, García, Magín, & Parra, 2021), hot spots are areas of high temperature that affect an area of the solar panel and result in a localized decrease in efficiency, and an acceleration of the degradation of materials in the area affected by high temperature (Benavides, Díaz, Roig, & Vaillant, 2022). .

The use of the thermographic camera serves to monitor the hot spots caused by stationary shadows, sand, dirt, partial shading among others, it is a method that uses images that show the temperature of the surface of the panels and allows to quickly locate and Exactly the irregular thermal areas that are affecting the photovoltaic plant in order to correct the problem in time that leads to the correct operation of the photovoltaic plant and minimize maintenance costs.

Materials and methods

To carry out the investigation, the Smart View software was used to carry out the thermographic inspection of the photovoltaic panels, it was applied in the inductive method of deduction and the qualitative and quantitative analysis, being able to corroborate the difficulties that can be caused by local conditions where the panels are installed. photovoltaic panels.

For Fluke Infrared Cameras and Visual Infrared Thermometers Fluke SmartView software is included with every Infrared Camera and Visual Infrared Thermometer. This powerful software is a modular solution of tools that allows you to visualize, optimize and analyze infrared images, also generate reports completelycustomizable.

Analysis and discussion of results

The planet, the global ecosystem, is going through critical moments due to the emission of a large amount of greenhouse gases, mainly carbon dioxide, which is produced disproportionately by the high burning of fossil fuels. Obtaining clean and renewable energy is one of the solutions that have emerged as an alternative to combat this global problem.

The report of the sixth evaluation of the Intergovernmental Panel on Climate Change or Intergovernmental Panel on Climate Change (IPCC) has conveyed a sobering message, leaving little ambiguity as to the need for immediate action, where it states that in this decade how successful it is in reducing greenhouse gas emissions will determine whether global temperature rise can be limited to 1.5°C or even 2°C. Within this time frame, the only realistic option available is a substantial expansion of renewable and efficient energy solutions (IRENA, 2023), for this reason, the vulnerability of photovoltaic panels in the areas where they are located should be studied.

In order for the photovoltaic system to function well and without complications, maintenance must be given to the solar panels, especially to be able to identify in time the difficulties to which they are subjected due to high temperatures that cause a decrease in efficiency, less power of output and an acceleration of the degradation of materials in the area affected by the high temperature (Cabezas, Franco, &Fasoli, 2018)

The use of the thermographic camera serves to monitor this phenomenon of hot spots caused by stationary shadows, sand, dirt, partial shading, among others (Poyato, 2023), it is a method that uses images that show the surface temperature of the panels and allows to quickly and accurately locate the irregular thermal areas that are affecting the photovoltaic plant in order to correct the problem in time that leads to the correct operation of the photovoltaic plant and minimize maintenance costs (Dávila, 2021).

A hot spot is called when the temperature of any conductor, device, or electrical element increases its resistivity and heats up to more than its normal temperature under normal operating conditions, this may be due to several factors, such as the increase in intensity or other parameter, which can exceed the nominal values for which they were designed, another factor may be the deterioration of the element due to its use, or factory damage, as well as other factors we can find the presence of harmonics, bad connections of the electrical system, phase imbalance among others (Solarama, 2023).

A photovoltaic power plant is a set of photovoltaic modules that work through the photoelectric effect to generate electricity in direct current, photovoltaic power plants are mainly made up of photovoltaic modules and an inverter (Rodríguez M., Vázquez, Torres, Vilaragut, & Castro, 2022).

The modules are in charge of capturing solar radiation and transforming it into electricity, and the inverter transforms direct current into alternating current (Oriol, P, 2021), they are susceptible to environmental conditions frequently affected by the dirt that is deposited on them. causing a decrease in generation. The application of a regular cleaning habit increases the energy productivity of each photovoltaic system, improving the amortization time of the photovoltaic system for energy self-sufficiency (energetic C., 2021).

For this project, the FLUKE TIS65+ thermographic camera will be used, which has the characteristics shown in table 1. with the following characteristics:

Table 1. Fluke tiS65 Thermal Imager Key Features

Feature	measure
detector resolution	320X240
infrared resolution	76,800 pixels
Standard field of view	24 ° H x 17 ° V
Minimum Focus Distance	15cm (approx. 6 inches)
Screen	3.5-inch (wide) 640 x 480 LCD
Screen Type	high resistance touch
Temperature measurement range	-20 °C a +650 °C (-4 °F y + 1202 °F)
integrated digital camera	Industrial performance with 5 megapixels
Laser pointer	And

Solar panels can often be subject to mechanical or careless damage such as dirt buildup due to poor maintenance which can cause a cell to break, this causes internal stress effects on the cells resulting in the appearance of the hot spots. Because of this, an increase in electrons is created that manifests itself in the form of heat, in this sense they can reach a temperature greater than

50°C, which is above the norm, causing irreversible damage to the entire panel.
When shadows appear on the panels, the propagation to the other panels must be prevented, although in home exchanges and in buildings it is very difficult to achieve this due to the low maintenance of the plant.
Not fighting the shading causes the cells not to originate, and on the contrary, they consume electricity, inducing overheating that damages the cell, resulting in the appearance of hot spots. For this reason, the panels have the presence of diodes, which act as a bridge only in the form of protection, minimizing hot spots (Castrillón, 2022).
The properties of a photovoltaic panel are marked under 1W/m^2standards and a temperature of 25°C. For the implementation of a photovoltaic plant, elements such as the charge regulator must be available, which serves as a connection to the batteries. Its main use is to ensure that the path of the current to the batteries and the load is safe, in such a way that it protects the batteries and the panels from an overload or electrical discharge. The solar battery must have a dimension that allows the correct operation of the plant, the most used are made of lead and acid. Its use is to store energy to use it when its use is required. The inverter is a device that converts direct current into alternating current depending on the use that is going to be given. The conductors must be well sized since a direct current circuit has a greater current than when they work in an alternating current circuit. Finally, the structure, which is where the panels will be placed, whether on roofs, buildings, or others, which must be verified to have an optimal degree of inclination that allows the best use of solar radiation.
One of the obstacles that has limited the implementation of photovoltaic systems in Ecuador has had an impact on the high costs that photovoltaic technologies have been offering. At present, the decrease in prices, the increase in quality and the longer useful life calculated for these technologies place them in the energy market with a high position. However, in Ecuador the price of photovoltaic energy is still high and does not It is greatly reduced even when the government has decided to free these technologies from tariffs for their entry into the country (Rodríguez & Vázquez, 2018).

Figure 1 shows the photovoltaic system where the study was carried out (Terrace building 1 of the Faculty of Sciences, Mathematics, Physics and Chemistry) of the UTM.

Figure 1. The power plant has a photovoltaic capacity of 3.4 kWp (A) and in (B) a panel with bird droppings.

As you can see, the panels, due to lack of periodic maintenance, contain bird droppings, which at some point can cause hot spots that can destabilize the generation of the system. Figure 2 shows the first thermography taken.

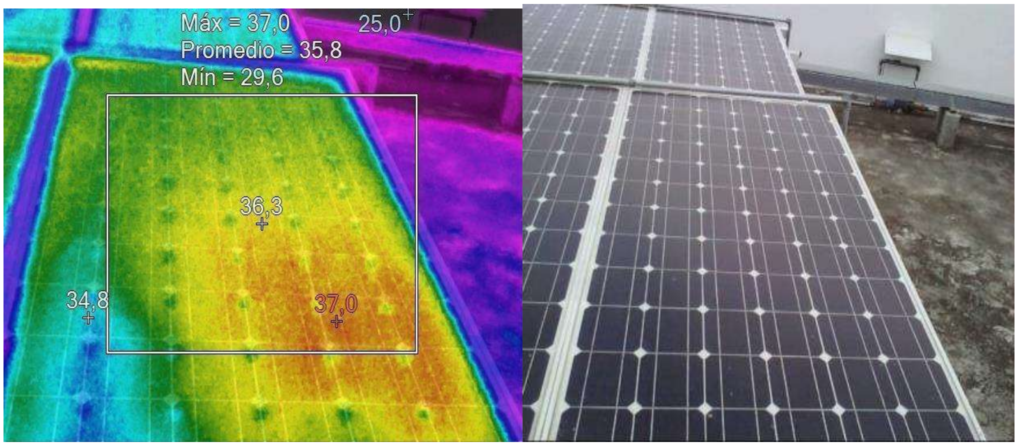

Figure 2. Thermography IR_05539.IS2

As can be seen, the temperature is at a maximum value of 37.0 degrees, knowing that according to the manufacturer, the working range of the module is between 40 and 85°C, it can be said that there are no hot spots.

Table 2 shows the information from the thermography performed.

Table 2. Thermography Information

emissivity	0.90
background temperature	26.0 °C
Transmission	100%
image range	25.0 °C a 37.0 °C
Average temperature	34.7 °C
Gravity	No problem found
IR sensor size	260x195

When making a temperature comparison of a range established by the photovoltaic panel in operation, giving a minimum temperature value of 25.0°C and a maximum temperature of 37.0°C. In this thermography the camera does not detect any hot spots in the module, from these data it can be concluded that the temperatures captured are within the range established as "normal" in its operation, even reaching a temperature of 40°C for the photovoltaic module. it would work at 80% of its capacity.

When concluding with the process of comparing the different temperatures that were presented in the photovoltaic panel, there are three strategic measurements of the system, the point with the hottest temperature, the point with the coldest temperature and the central point. Inside the panel, the point with the hottest temperature is 37°C located in the central-right part, the point with the coldest temperature is 34.8°C located in the central-left part and the central point with a temperature of 36.3 located in the center of the photovoltaic panel.

Several thermography’s were carried out and no anomaly was found in the system, it is only noted that in the lower part of the module due to dirt some variations were found as shown in figure 3.

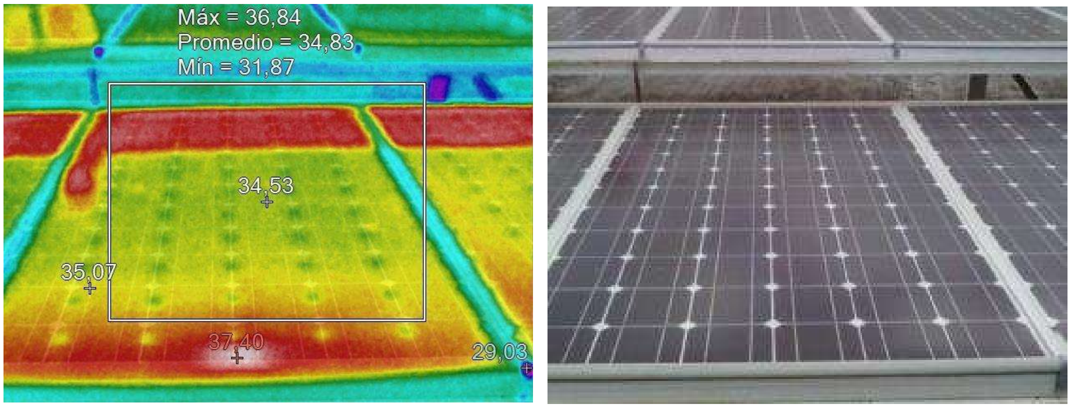

Figure 3. Dirt on the bottom of the module

As observed in the thermography of the figure, variations are noted in the parts of the module where there is accumulated dirt, inferring that the conditions must be created so that this does not happen, because poor maintenance over a period of time can cause the appearance of points hot. Table 3 shows the results of the thermography.

Table 2. Thermography Information

emissivity	0.90
background temperature	26.0 °C
Transmission	100%
image range	29.03 °C a 37.40 °C
Average temperature	34.51 °C
Gravity	No problem found
IR sensor size	260x195

Table 3 shows the marker data.

Table 3. Marker data.

Label	**emissivity**	**background temperature**	**Minimum**	**Average**	**Maximum**	**Standard deviation**
Hot (°C)	0.90	26	37.40	37.40	37.40	0
Center Square(°C)	0.90	26	31.87	34.83	36.84	0.94
Cold (°C)	0.90	26	29.03	29.03	29.03	0
P0(°C)	0.90	26	35.07	35.07	35.07	0
Center point (°C)	0.90	26	34.53	34.53	34.53	0

A temperature comparison of a range established by the photovoltaic panel in operation is carried out, giving a minimum temperature value of 29.03°C and a maximum temperature of 37.40°C. In this thermography, the camera does not detect any hot spot within said module, from these data it can be concluded that the temperatures captured are within the range established as "normal" in its operation.

When concluding with the process of comparing the different temperatures that were presented in the photovoltaic panel, there are three strategic measurements of the system, the point with the hottest temperature, the point with the coldest temperature and the central point. Inside the panel, the point with the hottest temperature is 37.40°C located in the lower central part, the point with the coldest temperature is 34.53°C located in the central part and point with a temperature of 35.07 located in the lower-left part of the photovoltaic panel.

conclusions

Panels tested with Fluke infrared camera technology and visual infrared thermometers did not show any hot spots that will affect generation in the system, just some temperature differences at the bottom of the panels due to dirt buildup.

Since photovoltaic energy is one of the renewable energies that has had the greatest impact worldwide and knowing that the panels require good maintenance, it is recommended to carry out periodic analysis in the places where they are installed, mainly cleaning them.

References

Benavides, J., Diaz, R., Roig, A., & Vaillant, L. (2022). Electroluminescence of polycrystalline silicon modules.*Energy Engineering, 43*(2). http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1815-59012022000200060

Cabezas, M., Franco, J., &Fasoli, H. (2018). Design and evaluation of a photovoltaic and thermal solar panel for dispersed populations in regions of great thermal amplitude.*Engineering, research and technology, 19*(2). https://doi.org/10.22201/fi.25940732e.2018.19n2.018

Castrillon, D. (2022). Detection of hot spots in photovoltaic systems. Retrieved from https://repositorio.itm.edu.co/bitstream/handle/20.500.12622/5857/Dany_CastrillonOcampo_2022.pdf?sequence=1

Dávila, M.A. (2021). Low-cost infrared thermography as a support for research on degradation of photovoltaic panels.*Faculty of Engineering Magazine University of Antioquia, 1*(01), 20-30. doi: https://doi.org/10.17533/udea.redin.20200689.

energetic, C. (2020). *Solar panels, most frequent defects*. Retrieved from https://www.cambioenergetico.com/blog/paneles-solares-defecto-frecuentes-primera-parte/

energetic, C. (2021).*energetic change*. Obtained from How dirt affects solar panels: https://www.cambioenergetico.com/blog/

Epeni, G. B., Rodríguez, M., Loor, G. A., Vázquez, A., &Nuñez, J. R. (2023). Influence of ambient temperature in the city of Portoviejo, Ecuador on the energy performance of photovoltaic modules. *International Journal of Electrical and Computer Engineering*

(IJECE), 13(1), 46~54. doi:DOI: 10.11591/ijece.v13i1.pp46-54

Fluke . (2023). *Fluke SmartView*. Retrieved from https://www.fluke.com/en-us/product/fluke-software/fluke-smartview-ir-mobile

IRENA. (2023). *World Energy, transitions perspectives 2023.* World Energy Transitions Outlook 2023: 1.5°C Pathway. Abu Dhabi: International Renewable Energy Agency. Retrieved from www.irena.org/publications

Leon, F., García, M., Magín, G., & Parra, a. (2021). Effect of dirt on the performance of photovoltaic modules in Bogotá.*Engineering, 26*(2). https://doi.org/10.14483/23448393.16601

León, F., García, M., Magín, G., & Parra, A. (2021). Effect of dirt on the performance of photovoltaic modules in Bogotá.*Engineering, 26*(2). https://doi.org/10.14483/23448393.16601

Navarro, E. (2022).*Thermal analysis of photovoltaic panels by thermography.* Thesis, Higher Technical School of Engineering, University of Seville. Retrieved from https://idus.us.es/bitstream/handle/11441/140539/TFG-4206%20Navarro%20Huerta.pdf?sequence=1&isAllowed=y

ORGMASTER. (2023).*ORGLMEISTER Infrared Systems GmbH & Co. KG*. Retrieved from https://www.orglmeister.de/es/historia-fisica-de-la-radiacion-infrarroja-camara-termografica/

Poyato, R. (2023).*Use of thermography in maintenance of photovoltaic plants*. (D. s. Ibérica, Editor) Retrieved from https://es.rs-online.com/es/pdf/RSFLUKEELECTRICIDAD04.pdf

Ramos, J. B. (2022). *Analysis of defects in Solar Panels of Photovoltaic Plants by means of Thermography and Electroluminescence.* University of Valladis. Retrieved from https://uvadoc.uva.es/bitstream/handle/10324/52181/TFG-I-2139.pdf?sequence=1

Rocha, J., &Povoas, Y. (2017). Infrared thermography as a non-destructive test for the inspection of reinforced concrete bridges: Review of the state of the art.*ALCONPAT Magazine, 7*(3). Retrieved from https://doi.org/10.21041/ra.v7i3.223

Rodríguez, M., & Vázquez, A. (2018).*Photovoltaic Energy in the Province of Manabí.* editions utm. Retrieved from https://www.utm.edu.ec/ediciones_utm/index.php/component/content/article?id=713:la-energia-fotovoltaica-en-la-provincia-de-manabies-teoricas-fundamentales- of-the-administration?Itemid=101

Rodríguez, M., Vázquez, A., Torres, M., Vilaragut, M., & Castro, M. (2022). Territorial planning with photovoltaic energy in the province of Cienfuegos.*Energy Engineering, 43*(1). Retrieved from http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1815-59012022000100058&lng=es&nrm=iso

Solarama. (2023). *What are hot spots in solar panels and how are they generated?* Retrieved from https://solarama.mx/blog/puntos-calientes-en-paneles-solares/#:~:text=Los%20puntos%20calientes%20o%20hotspots,la%20degradaci%C3%B3n%20de%20los% 20materials.