Open Access Research Journal of
Science and Technology
Journals home page: https://oarjst.com/
ISSN: 2782-9960 (Online)

OARJ OPEN ACCESS RESEARCH JOURNALS

(Research Article)

Check for updates

Drone-based thermal imaging system for identifying damaged photovoltaic modules

Cuong, Thai Hung *

Department of Technology, Dong Nai Technology University, Bien Hoa City, Dong Nai, Vietnam.

Open Access Research Journal of Science and Technology, 2023, 07(02), 028–033

Publication history: Received on 21 February 2023; revised on 29 March 2023; accepted on 01 April 2023

Article DOI: https://doi.org/10.53022/oarjst.2023.7.2.0023

Abstract

In this study, we found the temperature difference (MTD) between the normal part of a PV module and the damaged area is closely related to the efficiency of the module. Specifically, when the MTD is lower than a certain threshold, the efficiency of the module is significantly reduced. We also found that the MTD is closely related to the size of the damaged area. The experiment results of our study suggest that UAV and thermal imaging cameras can be used to detect and diagnose partially damaged PV modules with high accuracy. This can help reduce maintenance costs and increase the efficiency of PV systems. Moreover, this study provides a new method for diagnosing partially damaged PV modules, which can be used for further research.

Keywords: Defect of PV module; Thermal Imaging Detection; UAV Detection

1. Introduction

The UAV can fly over the photovoltaic system and take thermal images of the modules. By analyzing the thermal images, the system can detect the hot spots which indicate the potential damage of the PV modules [1-3].

Comparing to the traditional methods, this method can save a lot of manpower and time while still achieving the same accuracy. This method can effectively identify the faulting modules on the photovoltaic system by making use of the difference between the temperature of normal modules and the temperature of faulting modules. Thermal images of PV modules can be taken by UAV-mounted thermal imaging cameras, which can be piloted to fly over the photovoltaic system [4-5].

The analysis of thermal images can provide insight on the status of the photovoltaic system, such as the location of hot spots on the modules, the temperatures of the modules, and so on. With the help of a computer vision algorithm, the faulting modules can be identified in a much shorter time than traditional manual inspection. This method is also more efficient and cost-effective, since it eliminates the need for manual labor and reduces the amount of time required for detection [6].

The thermal imaging camera can detect the abnormal temperature of PV modules, which is a sign of potential damage. UAVs can fly over the PV system and take the thermal images efficiently and accurately. By analyzing the thermal images, the damaged PV modules can be located and repaired quickly. The process of using UAV and thermal imaging cameras for PV module damage detection has many advantages [7].

Firstly, it is much more efficient than traditional manual inspection methods. UAVs can fly over large areas in a very short time and take the thermal images of the entire photovoltaic system. With the help of image processing algorithms, the abnormal temperature of the PV modules can be detected quickly and accurately [8-9].

* Corresponding author: Cuong, Thai Hung

Secondly, it is very cost effective. UAVs can be operated at a much lower cost than traditional manual inspection methods. In addition, the cost of thermal imaging cameras is relatively low. It is much cheaper than buying large quantities of PV modules to replace the damaged ones [10].

Thirdly, it is safe. UAVs can fly over large areas without any danger to the technicians. Moreover, the thermal images can be used to detect the abnormal temperature of the PV modules without any physical contact.

In conclusion, the combination of UAVs and thermal imaging cameras can be used for effective and efficient damage detection of PV modules in a large area of photovoltaic system. It is cost effective, efficient and safe. It can provide an effective and efficient way to locate and repair damaged PV modules quickly [7-10].

The use of an unmanned aerial vehicle (UAV) equipped with a thermal imaging camera to detect damages in various photovoltaic (PV) modules can be extremely beneficial. This technology can be used to identify potential problems with the PV system before they become major issues that could lead to costly repairs or replacements. By using a UAV with a thermal imaging camera, the user can detect hotspots and other anomalies that may indicate a problem with the PV system. This technology can also be used to detect changes in temperature throughout the day, which can be indicative of a potential issue with the system. Additionally, the use of thermal imaging can help to identify damage caused by hail or other natural disasters, giving the user the opportunity to take preventive measures before the damage becomes too severe. Finally, the use of a UAV with a thermal imaging camera can also help to reduce downtime, as the user can quickly identify and address any issues before they become major problems [11].

The results show that the efficiency of the damaged module is lower than that of the reference module, and that the MTD increases as the damaged area increases. The amount of power generated is also reduced as the damaged area increases. The analysis program is able to accurately predict the amount of power generated by the damaged module according to the MTD and damaged area. The results of this experiment provide useful information for PV system operators, which can be used to assess the performance of damaged modules and to optimize the system layout and operation. Furthermore, this study demonstrates the potential of UAV thermal imaging for PV module monitoring and damage detection.

2. Material and method

The method to measure temperature difference (MTD) is a measure of the difference in temperature between the top and bottom of the PV module. It is used to assess the thermal behavior of the module and the impact of thermal losses on the module's efficiency. The lower the MTD, the better the thermal performance of the module.

Damaged area is the percentage of the module's surface area that is damaged, either by physical damage such as scratches, cracks, or deformations, or by environmental damage such as soiling, corrosion, or exposure to UV light.

The relationship between MTD and efficiency can be measured by comparing the efficiency of the undamaged module with the efficiency of the damaged module. If the MTD of the damaged module is higher than that of the undamaged module, then the efficiency of the damaged module is likely to be lower. Conversely, if the MTD of the damaged module is lower than that of the undamaged module, then the efficiency of the damaged module is likely to be higher than that of the undamaged module [12].

By comparing the MTD and efficiency of the undamaged and damaged modules, we can gain insights into the relationship between MTD, damaged area, and efficiency. This will allow us to assess the impact of damage on the module's efficiency and understand the optimal MTD for a given level of damage, Equation (1).

$$MTD = \frac{\sum(T_a - T_{normal})}{n_a} \quad \text{................(1)}$$

Where, T_{normal}: Normal operating temperature; T_a: Temperature above the T_{normal}; n_a: The number of temperatures below the average temperature.

The hardware design involves the selection of components such as the microcontroller, the solar cell, the voltage regulator, and the transistors. The microcontroller is used to control the system, while the solar cell and the voltage regulator are used to generate the necessary power for the system. The transistors are used to amplify the signals from the solar cell and the voltage regulator.

The software programming involves the creation of an algorithm that will detect the presence of a PV module. The algorithm will first measure the voltage output from the solar cell and the voltage regulator and then compare the two values. If the two values are within the specified range, then the system will detect the presence of a PV module. The algorithm can also be modified to detect the presence of other components, such as a battery or an inverter.

The system can be configured to send an alert or a notification when a PV module is detected. This alert or notification can be sent to a mobile device or to an email address. Additionally, the system can be configured to shut off the system when a PV module is detected. This will help to prevent the system from malfunctioning due to an overload of power.

The thermal imaging camera is connected to a laptop via USB port, for the purpose of image acquisition. The camera captures the thermal image of the target and sends it to the laptop. The laptop provides software to process the image and display it in real-time. The software can be used to calculate the temperature of the target and display it in a graphical format. The user can also choose to save the image or video of the target. The GPS is also connected to the laptop, to provide the location of the UAV. The location data is used to calculate the position of the target and the camera. The location data is also used to determine the altitude of the UAV, shown in Figure 1.

The video and audio transmission system is used to send the live video and audio from the UAV to the laptop. The laptop can be used to record and store the video and audio. The data from the thermal imaging camera, GPS, and video/audio transmission system are processed and analyzed by the laptop to provide the location, altitude, and temperature of the target. The result is then displayed on the laptop for the user to view.

The experiment demonstrates the feasibility of using UAVs equipped with thermal imaging cameras for remote sensing applications. The experiment also shows the potential of using UAVs for search and rescue operations. The results of the experiment can be used to improve the effectiveness of UAVs and their sensors in various applications, shown in Figure 2 and Figure 3.

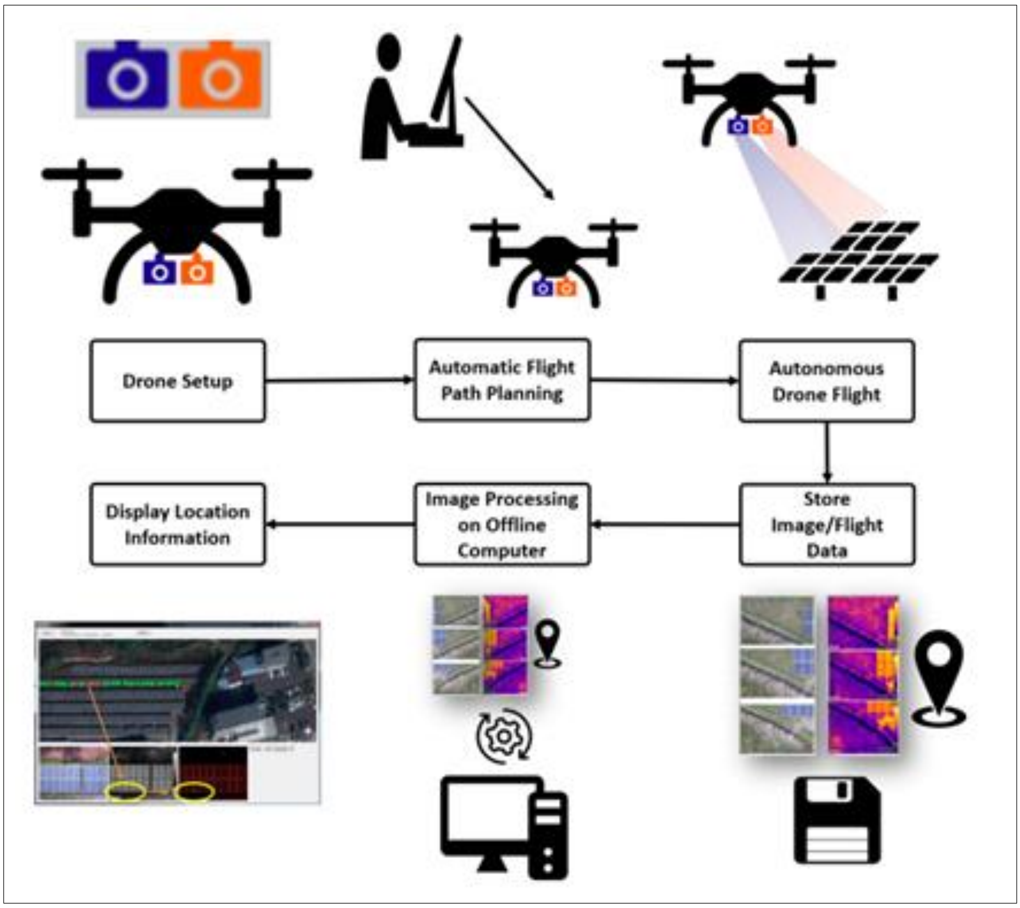

Figure 1 The thermal image processing system block diagram

(a) (b)

Figure 2 (a) UAV; (b)Thermal imaging camera

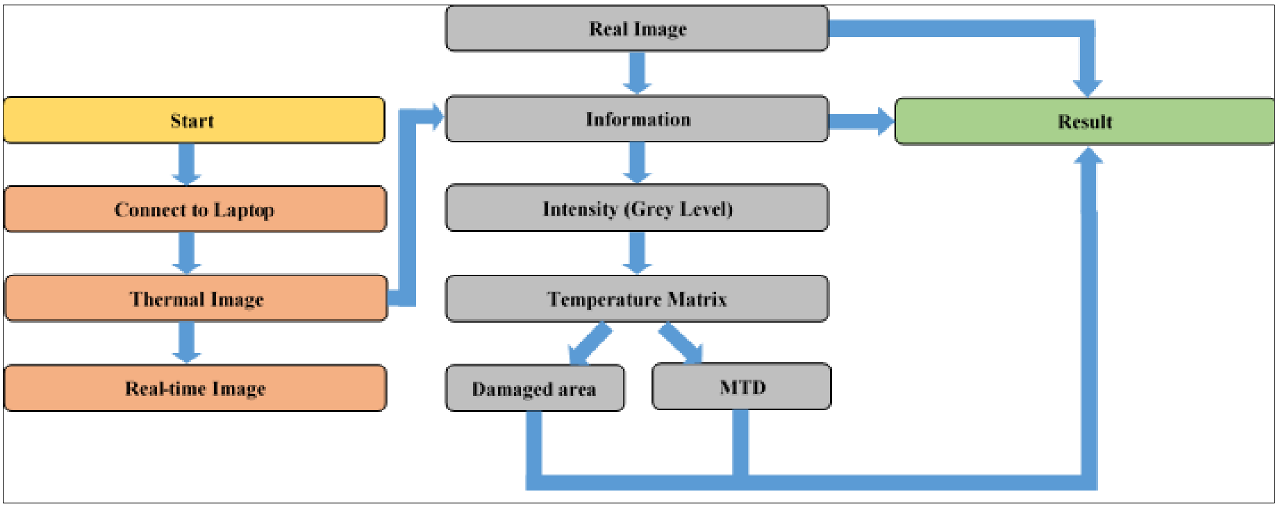

Figure 3 The software flow chart

3. Results

One of the detection results is shown in Figure 4 and Table. 1. A polycrystal silicon PV module with detect height 1.5 m and scan velocity 3.6 m/s. Also we measure the degree of damage by measuring I-V curves of the PV modules.

Table 1 Testing result of difference of damaged and undamaged PV module

	Damaged	Undamaged
Solar radiation	633 W/m^2	
Current	3.51 A	6.76 A
Voltage	33.7 V	34.2 V
Power	118 W	231 W
Decay	48.8 %	

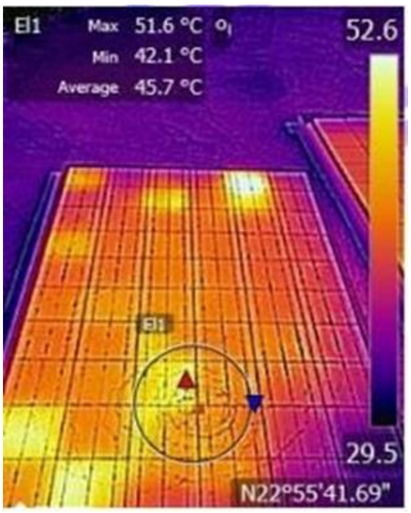

Figure 4 Damaged PV module in thermal image Detect height: 1.5 m, scan velocity: 3.6 m/s

4. Conclusion

Our study used UAV and thermal imaging cameras to detect various PV modules with partial damage. We examined the relationship between the mean temperature difference (MTD) and the damaged area, as well as the efficiency of the module.

We found that the MTD is closely related to the efficiency of the module. Specifically, when the MTD is lower than a certain threshold, the efficiency of the module is significantly reduced. We also found that the MTD is closely related to the size of the damaged area.

Our results suggest that UAV and thermal imaging cameras can be used to detect and diagnose partially damaged PV modules with high accuracy. This can help reduce maintenance costs and increase the efficiency of PV systems. Moreover, this study provides a new method for diagnosing partially damaged PV modules, which can be used for further research.

Compliance with ethical standards

Acknowledgments

The researchers acknowledge and appreciates all the mothers who participated in this study

Disclosure of conflict of interest

All authors contributed positively to the writing of this manuscript and there no conflict of interest as agreed to the content of this research.

Statement of informed consent

Informed consent was obtained from all individuals respondents included in the study

References

[1] Lee, Dong Ho, and Jong Hwa Park. "Developing inspection methodology of solar energy plants by thermal infrared sensor on board unmanned aerial vehicles." Energies 12, no. 15 (2019): 2928.

[2] Hwang, Myeong-Hwan, Young-Gon Kim, Hae-Sol Lee, Young-Dae Kim, and Hyun-Rok Cha. "A study on the improvement of efficiency by detection solar module faults in deteriorated photovoltaic power plants." Applied Sciences 11, no. 2 (2021): 727.

[3] de Oliveira, Aline Kirsten Vidal, Mohammadreza Aghaei, and Ricardo Rüther. "Aerial infrared thermography for low-cost and fast fault detection in utility-scale PV power plants." Solar Energy 211 (2020): 712-724.

[4] Vergura, Silvano. "Correct settings of a joint unmanned aerial vehicle and infrared camera system for the detection of faulty photovoltaic modules." IEEE Journal of Photovoltaics 11, no. 1 (2020): 124-130.

[5] Herraiz, Álvaro Huerta, Alberto Pliego Marugán, and Fausto Pedro García Márquez. "Photovoltaic plant condition monitoring using thermal images analysis by convolutional neural network-based structure." Renewable Energy 153 (2020): 334-348.

[6] Du, Bolun, Yigang He, Yunze He, and Chaolong Zhang. "Progress and trends in fault diagnosis for renewable and sustainable energy system based on infrared thermography: A review." Infrared Physics & Technology 109 (2020): 103383.

[7] Vega Díaz, Jhon Jairo, Michiel Vlaminck, Dionysios Lefkaditis, Sergio Alejandro Orjuela Vargas, and Hiep Luong. "Solar panel detection within complex backgrounds using thermal images acquired by UAVs." Sensors 20, no. 21 (2020): 6219.

[8] Greco, Antonio, Christopher Pironti, Alessia Saggese, Mario Vento, and Vincenzo Vigilante. "A deep learning based approach for detecting panels in photovoltaic plants." In Proceedings of the 3rd International Conference on Applications of Intelligent Systems, pp. 1-7. 2020.

[9] Sridharan, Naveen Venkatesh, and V. Sugumaran. "Convolutional neural network based automatic detection of visible faults in a photovoltaic module." Energy Sources, Part A: Recovery, Utilization, and Environmental Effects (2021): 1-16. Liao, Kuo-Chien, and Jau-Huai Lu. "Using uav to detect solar module fault conditions of a solar power farm with ir and visual image analysis." Applied Sciences 11, no. 4 (2021): 1835.

[10] Liao, Kuo-Chien, Hom-Yu Wu, and Hung-Ta Wen. "Using Drones for Thermal Imaging Photography and Building 3D Images to Analyze the Defects of Solar Modules." Inventions 7, no. 3 (2022): 67.

[11] Buerhop, Claudia, Lukas Bommes, Jan Schlipf, Tobias Pickel, Andreas Fladung, and Marius Peters. "Infrared imaging of photovoltaic modules A review of the state of the art and future challenges facing gigawatt photovoltaic power stations." Progress in Energy (2022).

[12] Alsafasfeh, Moath, Ikhlas Abdel-Qader, Bradley Bazuin, Qais Alsafasfeh, and Wencong Su. "Unsupervised fault detection and analysis for large photovoltaic systems using drones and machine vision." Energies 11, no. 9 (2018): 2252.