The thermography drone detects hotspots and faulty modules from the air.

Photovoltaic systems thermography from the air using drones

Ideally suited for the thermography drone with its high resolution and light weight: top-notch thermal imaging camera of the FLIR Tbx series.

The company paul kitawa (www.kitawa.de) is located in Calau, Germany and is specialized in film productions. In addition to advertising, training, corporate image and product films, it provides its customers with aerial video recordings using drones. Within the context of these aerial recordings, the owner of paul kitawa, Mario Hambsch, came into contact with the subject of thermography in 2011 and developed a thermal imaging camera drone based on the FLIR T620.

"One of our customers from the energy sector (uesa GmbH, www.uesa.de) approached us at the time and asked if we could record images with our drones using thermal imaging cameras to monitor large-scale photovoltaic systems", says Mario Hambsch. He replied that it was possible in principle, but also knew that he would have a lot of development work.

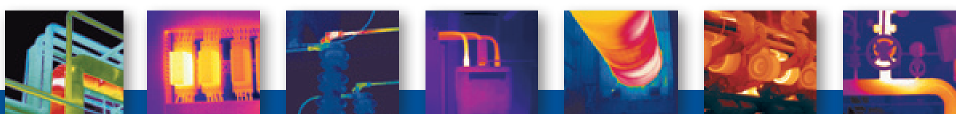
Photovoltaic thermography from the air

Thermography is ideal for inspecting photovoltaic systems. An infrared camera detects temperature differences in or on a photovoltaic module and visualizes them in a thermal image. During normal operation, thermal images of a properly functioning photovoltaic module will show homogeneous temperature distribution in the module. If a module is faulty however, significant temperature differences can be seen in individual cells or all of the module's cells. Therefore detection of errors with high definition thermal imaging cameras mounted on photovoltaic drones is an efficient and cost-effective way to ensure sustained profitability of a photovoltaic system.

Requirements and competent partners

The first step for Mario Hambsch in developing a thermography drone consisted of seeking competent partners. In addition to regional thermography partners throughout Germany, he partnered with the engineer Matthias Maus (www.solar-diagnose.de),

The drone consists of an octocopter, the FLIR T620 and a vertically tilting camera fastener with a total weight well under 5 kg.



Mario Hambsch with the drone's remote control and the measuring kit, on the monitor on which the live stream is displayed. The infrared live stream is transmitted to the ground station on an ongoing basis, recorded by a digital recorder and displayed on the monitor of a special measuring kit. On the left side of the tripod: the antenna for the connection to the drone and the thermal imaging camera.

who is a TÜV certified photovoltaic systems expert and experienced thermographer. Mario Hambsch then precisely defined the criteria for selecting the right thermal imaging camera for the job. The device was to have a high infrared resolution, so that thermal images could be recorded of larger areas of the installed photovoltaic modules from great heights. Ideally the camera would support wireless connections to transmit the infrared image to a ground station via video stream. In addition to this, the camera would have to be relatively light, because the drone could not exceed a total weight of 5 kg. "Individual take-off permits are required starting at 5 kg. That would have caused considerable extra effort as compared to the general take-off permit that we have for our drones", explains Mario Hambsch.

Development of the infrared drone

Based on these criteria, Mario Hambsch selected the FLIR T620, a top-notch model from the global leader in thermal imaging cameras FLIR Systems (www.flir.com). The camera has an excellent infrared resolution of 640 x 480 pixels, weighs on 1.3 kg and can easily be controlled using a tablet PC and wireless LAN.

"In the beginning, our combination of drone, thermal imaging camera and fasteners weighed just under 5 kg, but was still too heavy to allow for sensible flight times," says Mario Hambsch of one of the difficulties that had to be overcome. Together with Dr. Rolf Gußer of Gußer Metallbau GmbH (www.gusser-mb.de) from Cottbus, Mario Hambsch developed a lighter fastener solution, which ensured satisfactory flight times while also allowing for vertical tilting of the camera.

Technical procedure and calibration

Paul kitawa has since become a specialist in monitoring photovoltaic systems with high resolution thermography drones. The thermography drone produces no emissions, is efficient with regard to time and costs and detects all thermal anomalies when properly calibrated. In addition, the company is working with engineer for information technology Detlev Schuch to continue developing its modular drone system in order to adapt to customer requirements. The high radiometric resolution of the FLIR T620 of 640 x 480 pixels allows paul kitawa to inspect large areas of solar panels for thermal anomalies cost effectively in a short time. Significant temperature differences make faulty solar modules visible.

Transmission of data to the ground station

Mario Hambsch originally planned to use a wireless LAN connection to transmit the thermal imaging camera's live stream, because the FLIR T620 can be controlled via WiFi using a tablet PC. However, as experience showed the wireless LAN option turned out not to be ideal for outdoor flights. "Wireless LAN connections often only function properly at distances of 40-80 m and our drone is quickly further away than this", says Mario Hambsch. "And try to detect something on an energy-saving iPad screen outside in bright daylight."

Larger-scale systems can easily be monitored using a drone.

He therefore worked together with the information technology expert to develop an alternative solution, in which the camera can be controlled over distances of up to 2 km using the drone's own radio control.

The drone control software is a modular system, which Mario Hambsch has modified respectively. An electronic unit communicates with the camera so that the drone operator and/or the accompanying thermographer can turn on and focus the camera using two switches. The live stream from the drone is transmitted to the ground station on an ongoing basis, recorded by a digital recorder and displayed on the monitor of a special measuring kit.

A team consisting of a thermographer and a drone operator

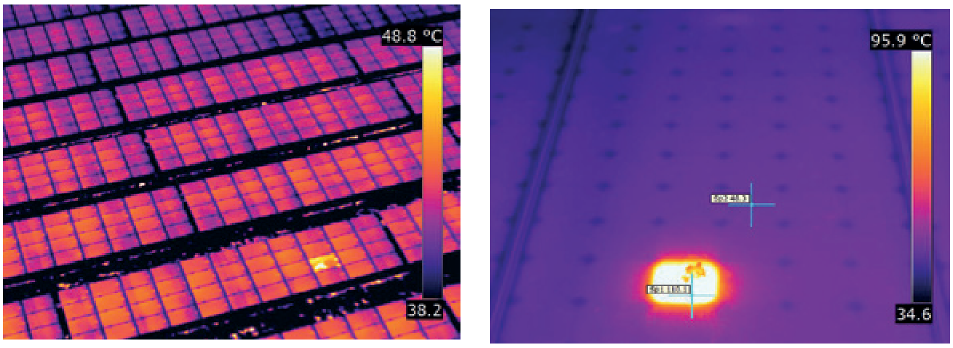
A thermography and flight team always consists of at least two people at paul kitawa: The drone operator and an experienced thermographer. Mario Hambsch is very experienced at flying the drone and can control the device even without using GPS. "If GPS fails, manual controlling can be quite tricky for inexperienced pilots. Wind can just blow the drone away. Experience is required to navigate in such situations." If the drone loses contact with the operator, a fail-safe system is activated, which lands the drone slowly to prevent worse things from happening. After all, the technology is not cheap. "Even though the drone and camera are insured, you don't want to lose contact often."

Training and thermography expertise

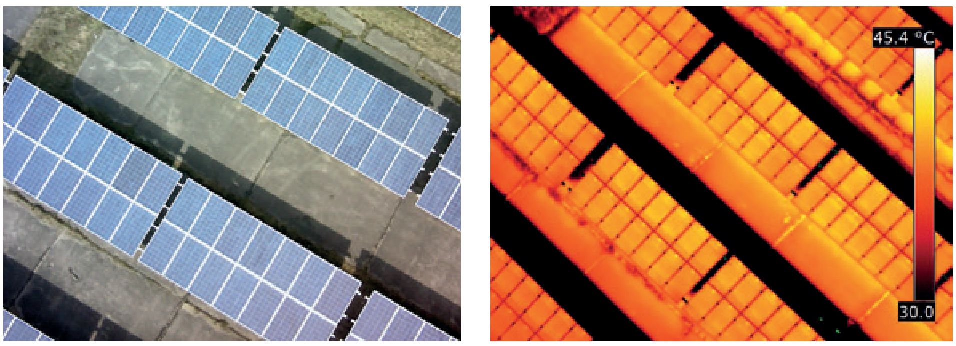
Even though Mario Hambsch took part in a basic thermography course, he always relies on an experienced thermographer for qualified analysis of the thermal images. He is always on location, focussed the camera via remote, takes the images and subsequently evaluates them. Mario Hambsch generally has enough to do controlling the drone anyway. But the analysis quality is also a decisive factor, as seen in the experience gained working with the engineering office Maus.

"The technical part is important, as is the experience in thermography. You can't seriously inspect photovoltaic systems from the air using a 160 x 120 pixel camera and, by the same token, professional analysis of the condition of the modules requires a lot of experience," explains Mario Hambsch. But if the requirements are met, then thermographic analysis of photovoltaic systems is very reliable, as shown by a study conducted by Claudia Buerhop-Lutz from ZAE Bayern in 2011 (www.eupvsec-proceedings.com/proceedings?paper=12852). As part of the study, the scientist first took thermographic images of a rooftop photovoltaic system and then fully took it apart in the lab. The lab results confirmed the theory: thermography had revealed all of the faults and defective modules.

Certified engineer Matthias Maus and Mario Hambsch examine up close a photovoltaic module detected as faulty from the air.



Thermography from the air: hotspot on a photovoltaic module.



Recognisable on the thermal image on the right, but not a defect: Junction boxes (light dot on the right side in the middle of the module) and the stand construction, which can be seen as a light parallel line.

Special characteristics of thermography – the right angle

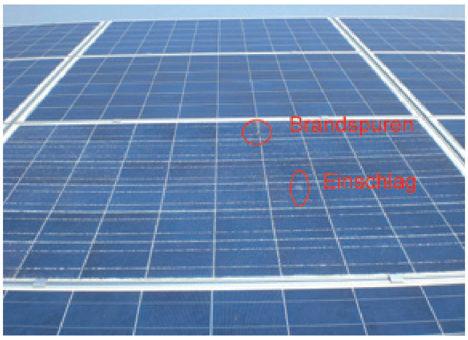
Detecting thermal anomalies in solar modules has to be carried out at a 70 to almost 90 degree angle to the module level. Due to the required inspection angle, large-scale systems could not be examined without complex technology and a lot of time using a manually operated infrared camera. The flight robot on the other hand, allows you to achieve the right angle on any photovoltaic system and quickly creates infrared recordings.

Regular inspection also serves safety purposes

Operators of large-scale photovoltaic systems are aware of the need for maintenance and regular inspection and use this to ensure the highest possible yield of the solar modules, but owners of smaller rooftop systems are often not aware of this. This is because small systems are often marketed by manufacturers as "maintenance free", but they're not. Annual visual inspection and thorough maintenance every 4 years is recommended, including inspection of the wiring and power inverter. Serious housefires caused by rooftop photovoltaic systems show how important this is.

Advantages of using drones in combination with thermography as opposed to helicopters

One important advantage of using drones instead of helicopters is the effort required. "I know of cases in which 5-digit figures were charged for 4-5 hours of thermography with a helicopter", says Mario Hambsch and tells of curious cases (hopefully) from the past. "Finding detected errors is a big challenge for anyone and there have been some very adventuresome attempts to mark the defective modules from the air in order to find them later", he says.



Traces of fire and impact on a photovoltaic module are not always clearly visible to the naked eye.

Other disadvantages of thermography from a helicopter: The wind caused by the rotors cools the photovoltaic modules, which can distort the results, and also causes dust or harder materials like sand to cover the system, which could potentially cause permanent damage.

Automated testing procedure

Mario Hambsch is currently working on automating his testing procedure to the greatest extent possible. This requires a third employee (in addition to the camera operator and thermographer) to drive between the individual modules with a bicycle or model car. The drone then automatically follows the signal. If the thermographer detects anomalies in the infrared live stream, then the drone is stopped in the air, the thermographer focusses the T620 and makes 2-3 thermal images, while the other employee marks the spot on the ground in order to be able to easily find it again later on (or he makes a photo of the defective module or the serial number).

Conclusion and outlook

Mario Hambsch can be proud of what his thermography drone can accomplish, because it has proven itself to be a practical and reliable means of detecting all serious defects in photovoltaic systems from the air. "We will continue developing our modular drone system and thus adapt to customer requirements", explains Mario Hambsch. Looking to the future, Mario Hambsch is looking forward to new challenges in thermography from the air.

Contact us for further information on thermal imaging cameras and this application.

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