



FLIR-FEATURED RPA MAKES REMOTE ENERGY PLANT INSPECTIONS MORE PRODUCTIVE AND AFFORDABLE

Nimbus RPAS with thermal kit from INPROTEC IRT featuring FLIR Ax5-Series thermal camera put to the test at the Department of Energy - Politecnico di Milano University.

From wind turbines to industrial production plants, when cooling towers or insulated roofs are involved, drones or Remotely Piloted Aircraft Systems (RPAS) have proven to be a very reliable and accurate tool for faster and more complete industrial inspections and surveillance. Nimbus S.r.l., a safety-oriented RPAS constructor, joined forces with FLIR distributor INPROTEC IRT and the SolarTech Lab of the Politecnico di Milano University to construct a professional inspection solution for industrial applications and photovoltaic power plants based on drone-mounted FLIR A35/65 cameras. Coupled with high-quality visible sensors, and controlled by a custom developed onboard PC, FLIR thermal cameras provide the drone operator with precise temperature data, thus making a complete inspection possible in a quick overflight.

INSPECTIONS FROM THE AIR

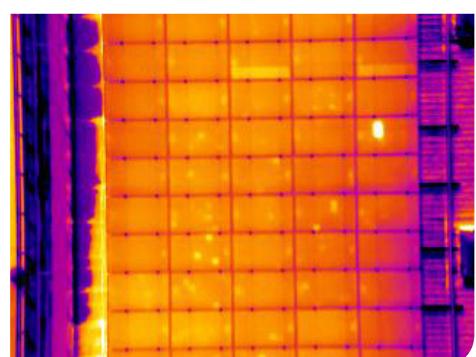
Over the last decade, the use of solar energy has expanded into a wider range of applications, including power plants, industrial applications, buildings, telecommunications and space. The use of RPA systems for monitoring energy applications has not been researched adequately yet, due to its novelty and to the many regulations. However, RPA systems have a lot of potential for monitoring photovoltaic plants, and they can

even outperform traditional industrial maintenance procedures, because they are a lot cheaper and less risky.

In many cases, information collection with RPAS is more reliable and precise and ten times faster than ground-based inspections. Italian RPAS constructor Nimbus immediately saw the added value, both from a technical and economic standpoint, of performing industrial inspections with RPAS, rather than with manned



The Nimbus PPL612 is a lightweight RPAS with six rotors and 5.3 kg Maximum Takeoff Weight (MTOW).



Example of PV module defects detected by FLIR Ax5 camera



Nimbus PPL 612

vehicles or by human operators. In an experimental set-up, Nimbus combined a lightweight RPAS with a FLIR A65, for remote inspection of a photovoltaic (PV) power plant.

MAINTENANCE OF PV PLANTS

The presence of PV plants has grown across Europe, thanks to financial incentives. However, very often the overall quality of these plants is not as expected. The number of distributed PV plants producing electricity has increased significantly and most of the installations are now decentralized.

Increased attention has been paid to the system performance of PV plants: these systems should be efficient, reliable, safe and stable in order to control and correctly predict energy flows. Maintenance of PV plants is therefore very important to ensure energy efficiency, safety, reliability, and cost-effectiveness.

The new, lightweight Nimbus RPA system is an ideal tool for energy equipment monitoring, thanks to its fast detection, large area coverage, cost-effectiveness, real-time imagery and light weight. Recent innovations

in UAV technology, sensors, and control systems by the company Nimbus have made it possible to use unmanned aerial vehicles for the inspection and monitoring across different energy plants.

RPAS IN ENERGY APPLICATIONS

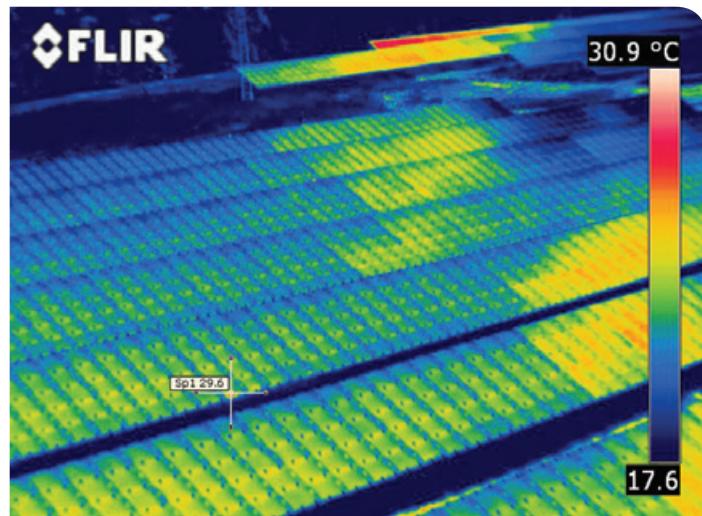
Generally, micro- and mini-RPAS are utilized in low-altitude and uncontrolled airspace. Typically, lightweight RPAS, with a load less than 150 kg, are appropriate for monitoring tasks in many practical industrial applications. Normally, the speed of an RPAS will vary roughly from tens to hundreds of kilometers per hour. A low-speed RPAS like the NIMBUS PPL 612 is more useful for inspection purposes. The NIMBUS PPL 612 RPAS is equipped with a thermographic kit from INPROTEC IRT and a FLIR Ax5 camera. Thanks to its architecture, designed to be safe and reliable, the PPL 612 was chosen by Politecnico di Milano University to survey PV fields and collect data for PV performance analysis.

EXPERIMENTAL STUDIES AT SOLARTECH LAB

The Solar Tech Laboratory, a department of the Politecnico di Milano University, focuses on experi-



The thermographic kit developed by INPROTEC IRT allows operators to record both the radiometric video and single radiometric images during the flight.



This thermal image shows large areas with elevated temperatures. Without more information, it is not obvious whether these are thermal anomalies or shadowing/reflections.

mental investigation of electrical and thermal power generation based on solar energy carrying. The research institute also undertakes experimental studies to discover a reliable and cost-efficient method to monitor the performance of PV plants by lightweight RPAS. An experimental study performed in collaboration with Nimbus was carried out across different operating plants in Italy.

The institute has used both visual and thermal sensors to detect defects or anomalies in PV modules. In a number of experiments, Nimbus and Solar Tech demonstrated that thermal cameras are a reliable, fast and cost-effective tool to detect defects like hot spots or snail trails in a fast way.

RPAS WITH THERMAL VISION

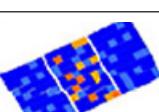
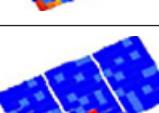
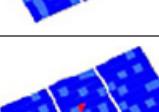
The Nimbus PPL 612 is a lightweight RPAS with six rotors and 5.3 kg Maximum Takeoff Weight (MTOW). The double avionics and redundant batteries make it reliable and safe to fly over PV plants. The system's impressive flight stability and professional-focused flight modes give the remote pilot the possibility to control the RPAS with great precision during the flight. The system allows the RPAS operator to get the best out of the FLIR A65 camera and to obtain an accurate map of single PV cell defects.

The thermographic kit developed by INPROTEC IRT allows operators to record both the radiometric video and single radiometric images during the flight. Every recorded image is also saved with integrated

GPS data. The kit is compatible with FLIR's Ax5, A615, A655sc and similar camera models. The RPAS operator can see the video in real time from the ground and command a start and stop of the recording. Before the flight it is possible to set all specific FLIR camera and recording parameters.

The Ax5-Series are cost-effective infrared cameras, with the FLIR A5 being the most affordable. They are ideal tools for putting thermal imaging at work in an automation, machine vision or UAV environment. All models are extremely compact.

"The FLIR Ax5-Series is an ideal camera solution for this application," comments Luciano Betti, sales manager at INPROTEC IRT. "One of

Pattern	Description	Possible failure reason	Observed	Electrical measurements	Remarks
	One module warmer than others	Module is open circuited – not connected to the system	Yes – suspicious	Module normally fully functional	Check wiring
	One row (sub-string) is warmer than other rows in the module	Short circuited (SC) or open sub-string - Bypass diode SC OR - Internal SC	No	Sub-strings power lost, reduction of VOC	May have burned spot at the module One diode shunted
	Single cells are warmer, no pattern (patchwork pattern) is recognized	Whole module is short circuited - All bypass diodes SC OR - Wrong connection	Yes – suspicious	Module power drastically reduced, (almost zero strong reduction of VOC)	Check wiring All diodes shunted
	Single cells are warmer, lower parts and close to frame hotter than upper and middle parts	Massive shunts caused by potential induced degradation (PID) and/or polarization	No	Module power and FF reduced Low light performance more affected than at STC	Change array grounding conditions – recovery by reverse voltage (PID)
	One cell clearly warmer than the others	- Shadowing effects - Defect cell - Delaminated cell	Yes – suspicious	Power decrease not necessarily permanent, e.g. shadowing leaf	Visual inspection needed, cleaning (cell mismatch) or shunted cell (delamination)
	Part of a cell is warmer	- Broken cell - Disconnected string interconnect	Yes – suspicious	Drastic power reduction, FF reduction	(cell cracks) (burn marks) (interconnects)

List of typical module errors and possible solutions

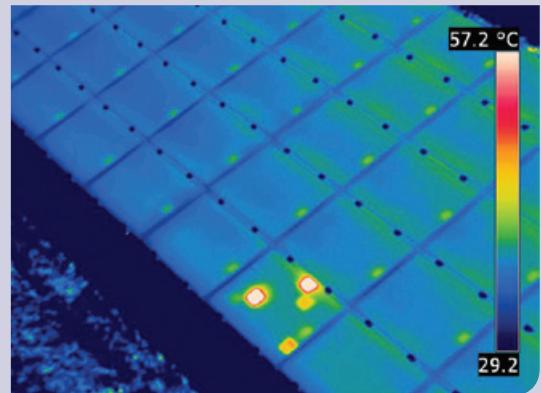
FLIR A65 / A35 / A15 / A5 Compact Thermal Imaging Ideal for Mounting under a UAV



The FLIR Ax5-Series is the perfect solution for those applications that require the benefits of a thermal image.

The Ax5-Series are low-cost infrared cameras, with the FLIR A5 being the most affordable. They are ideal tools for putting thermal imaging at work in a RPA environment. All models are extremely compact and have low power consumption. They can easily be integrated under RPAs.

The FLIR A65 produces crisp thermal images with 640 x 512 pixels. Users that do not need this high image quality for their application can choose for the FLIR A35, which produces thermal images of 320 x 256 pixels or for the FLIR A15, which produces thermal images with 160 x 128 pixels or the FLIR A5, which produces thermal images with 80 x 64 pixels. The FLIR Ax5-Series makes temperature differences as small as 50 mk clearly visible.



This thermal image shows an example of the so-called 'patchwork pattern', which indicates that this panel has a defective bypass diode.

the main benefit of our application is that we can offer full radiometric video streaming from the ground in real time. Each radiometric video frame coming from the FLIR camera has integrated GPS and temperature data. The Ax5-Series allows us to collect high-resolution images much faster than is possible with competitive camera models. The FLIR cameras are rugged, lightweight, easy to install and very affordable, especially in comparison with certain portable camera models."

FAST AND ACCURATE MONITORING OF PV CELLS

Reliable information about the performance of PV systems is critical for the overall planning of a PV plant and for the PV system's prognosis of future performance. FLIR thermal cameras are an essential part of this information collection. Mounted on an RPA

system, they can even detect defects, like hot spots, snail trails, micro-cracks and unwanted shadows, effectively across several PV modules.

The affected PV cell and the related panel can be monitored or adapted before complete degradation in a proactive way during maintenance operations. Engineers can recommend mitigation solutions or change parts. Information on underperforming panels can serve as input for future replacement policies. Another benefit of using thermal imaging cameras is that the inspection can be carried out during PV panel operation. The combination of a lightweight RPAS and FLIR mounted cameras therefore enable a rapid evaluation of a large number of PV modules.

For more information about thermal imaging cameras or about this application, please visit:

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