INFRARED (IR) DRONE FOR QUICK AND CHEAP PV INSPECTION

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ABSTRACT: The Photovoltaic Laboratory (PV LAB) at Bern University of Applied Sciences BFH in Burgdorf, Switzerland, developed its own remotely-controlled IR Multicopter Drone. The aim was to economically optimise the quality-control of predicted energy yields from PV-installations in the Swiss PV monitoring network as operated by the PV LAB since the 1990s. The work is carried out within the SCCER FURIES project and in collaboration with Swiss industry partners. The drone system was assembled in a Bachelor thesis and extensively tested on the PV LABs own roof-top PV-installation. Application to two large Swiss PV-installations (football stadium "Stade de Suisse", Bern / 1.3 MWp and open-field "Mont Soleil" in the Jura Mountains / 554.5 kWp) confirmed the economic benefit of remotely-controlled drone inspection as compared to manual thermographic examination. The IR Multicopter Drone now allows a rapid thermal survey of operating PV-modules at all installations in the Swiss PV monitoring network. As the system is electric, it offers an added value for thermal inspection of PV-installations where no disturbing emissions are allowed. This is a requirement at the world's highest research facility at Jungfraujoch (3 454 m asl) where the PV LAB measures the longest energy yield record from PV in the Swiss Alps.

Keywords: Degradation, Economic Analysis, Monitoring, Reliability

1 INTRODUCTION

With the trend towards the construction of large photovoltaic (PV) installations, quality-control of the predicted energy yields becomes increasingly demanding. Where manual thermographic examination may be too time-consuming or even impossible because of complex topography or buildings, remotely-controlled drones with thermal imaging camera on board may offer a cost-effective solution. In view of the above challenges, the Photovoltaic Laboratory (PV LAB) at Bern University of Applied Sciences BFH in Burgdorf, Switzerland developed its own infrared multicopter drone [1].

The PV LAB has operated a Swiss PV monitoring network since the 1990s [2] and now aims to economically optimise the quality-control of these PV-installations. The IR Multicopter Drone to be developed was expected to offer a relatively cheap method and simplify the regular inspection of these PV-installations.

The research work on the drone was initially carried out in the frame of a Bachelor thesis in 2014 [1]. It is supported by the Swiss Center of Competence in Energy Research on the Future Swiss Electrical Infrastructure, SCCER FURIES [3] and Swiss industry partners.

2 TECHNOLOGY

2.1 Drone components

The multicopter was supposed to be economically competitive and hence, self-construction was envisaged as opposed to purchasing a turnkey solution. It needed to be sufficiently strong to carry large batteries. Another condition was a reliable actor on the market so that spare parts can easily be obtained in the future.

Given the above requirements, the "Spreading Wings S1000" model with eight motors from the DJI, the market leader in China, was hence selected (Fig. 1).

Figure 1: The IR Multicopter Drone assembled by the PV LAB at BFH Burgdorf, Switzerland (model S1000 octocopter with camera-system). Photo: BFH-TI.

It weighs ca. four kilograms and can lift loads up to six kilograms (including battery). The flight control to steer the multicopter is from XAircraft, also a Chinese company.

A GoPro action camera is installed to record comparison shots. The infrared camera system installed is the "PI Lightweight" model from the German company Optris, a new development at the time the drone components were evaluated in 2014.

This infrared camera records a fully radiometric video at 35 Hz with a digital resolution of 382 by 288 pixels. The video is saved locally, and a live video is streamed to the pilot to check on the images of the two cameras. Both cameras are connected to the video transmitter via a switch. The pilot can switch between the two video signals during the flight recordings.

2.2 Drone testing

Extensive drone testing was performed on the roof-top PV-installation at the BFH building in Burgdorf, Switzerland [4]. This installation (Fig. 2) has been operational since 1994, is composed of 1,056 Siemens M55HO modules and inverters from Edisun, ASP (Topclass), Fronius and Sputnik (SolarMax) and has today a power output of about 50 kWp.

Figure 2: Roof-top PV-installation at BFH Burgdorf, Switzerland, where the drone was tested. Photo: BFH-TI.

The time needed to manually IR-map this PV-installation is about an hour. The IR-mapping using the IR Multicopter Drone took only 4 minutes as the recording of videos (as compared to taking high-resolution IR camera images) allows a rapid overflight of the entire PV-installation. In this way, the inspection results can quickly be analysed on-site, followed by a detailed analysis of the thermal images and further inspection of faulty PV modules in the PV LAB.

3 APPLICATION TO ROOF-TOP INSTALLATION

3.1 Football stadium “Stade de Suisse” in Bern

After testing, the IR Multicopter Drone was applied to inspect the “Stade de Suisse” in Bern in 2014, the then world-wide largest stadium-integrated PV-installation with a capacity of about 1.3 MWp (Fig. 3). The objective of the thermografic examination was to quantify the extra energy yield gained from cleaning the PV modules. Thus, the entire PV module surface was IR-mapped with the drone before and after cleaning.

Figure 3: Roof-top PV-installation on the football stadium “Stade de Suisse“, Bern, Switzerland. Photo: BFH-TI.

The drone was controlled from the sloping roof equipped with trapezoidal sheet metal, and the PV-modules were used as a take-off and landing area. Some turbulences, caused by updrafts, were encountered at the outer plant sections. With GPS-support, it was relatively easy for the drone to compensate them. As the drone weighs less than thirty kilograms and was not operated over people, no permission was needed from the Federal Office of Civil Aviation in Switzerland, and the consent of the stadium operator was sufficient to fly the drone.

3.2 Experiences

IR-mapping of the entire PV-installation on the “Stade de Suisse” took about 30 minutes. The thermal images allowed the on-site detection of the qualitative condition of the PV-modules and localization of “hot spots” (Fig. 4).

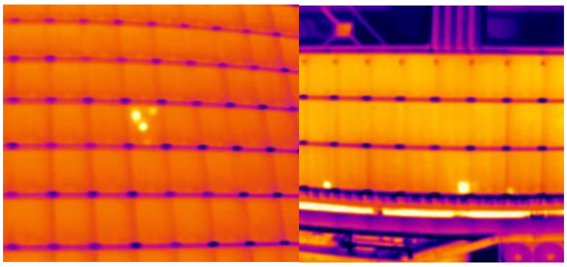

Figure 4: Faulty PV-modules on the “Stade de Suisse” Bern, likely caused by firework during a football play.

The real-image camera discovered mechanical damages on some PV-modules (e.g., shattered glass, but no thermal abnormalities). Fig. 4 illustrates some of the defective modules displaying mechanical defects from an impact, which affected the solar cells.

4 APPLICATION TO OPEN-SPACE PLANT

The open-space PV-installation “Mont Soleil” in the Jura Mountains (Fig. 5a) was put into operation in 1992 and has been monitored by the PV LAB at BFH since then. The 10,464 modules (Siemens M55) cover an area of 20,000 sqm (about 3 football fields) and produce an energy yield of 554.5 kWp.

Figure 5a: PV-installation “Mont Soleil” at 1 270 m asl in the Jura Mountains. Photo: sol-E Suisse.

As opposed to the PV-installation on the "Stade de Suisse" (Section 3), the thermal inspection of the ground-based, open-field "Mont Soleil" PV-installation in the Jura Mountains can be made by hand. IR-mapping of the entire "Mont Soleil" PV-installation with the drone was, however, quicker by a factor of 10-15 than manual inspection, requiring 16 minutes only.

One battery charge was sufficient to inspect the entire PV-installation. Because of the topographic situation, strong winds can occur at the "Mont Soleil" PV-installation. Using GPS support, these could easily be compensated for by the IR drone. Therefore, good shots were possible even at a brisk flight pace. However, experiences strongly recommend that a clear sky is beneficial to avoid reflections of clouds in the modules (Fig. 5).

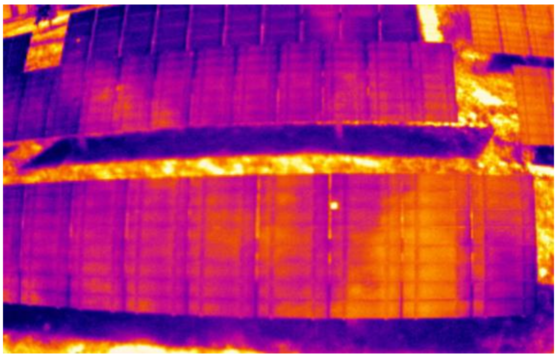

Figure 5b: Inspection results of IR-mapping the "Mont Soleil" PV-installation, revealing "hot spots" and cloud effects on the recorded thermal images, i.e., glass reflecting the radiated temperature.

5 CONCLUSIONS

5.1 Benefits and Recommendations

The IR Multicopter Drone developed at the PV LAB at BFH Burgdorf, Switzerland, was extensively tested on the roof-top PV-installation at the BFH-building hosting the PV LAB. Application of the drone system to two large PV-installations in Switzerland (complex building, difficult topography) provided valuable experiences and evidenced economic benefit.

Application to the "Stade de Suisse" PV-installation confirmed the economic value of a remotely-controlled system, as manual thermal inspection of the roof-top PV modules on the football stadium would only have been possible at big expense. The video of the IR Multicopter Drone allowed for a quick identification of defective modules on-site, which could immediately be replaced to avoid power loss.

At the "Mont Soleil" PV-installation, permanent adjustment of the flying altitude was necessary given the steep terrain, despite the electronics considerably ease the drone control. For open-field PV-installations larger than "Mont Soleil", automated flights could be an advantage.

Generally, the future flight time can significantly be shortened with additional practice in operating the IR drone.

5.2 Outlook

The IR Multicopter Drone now allows a rapid thermal inspection of operating PV-modules in the Swiss PV monitoring network. Since the drone is electric, it offers an especially added value for thermal inspection of PV-installations where no disturbing emissions are allowed. This is the case at the world's most elevated research facility at Jungfraujoch (3 454 m asl) in the Swiss Alps, with its highly sensitive instruments measuring trace gases in the lower free troposphere over Continental Europe [5].

After 2016, the thermal images from the 30 minute U-shaped drone flight paths over the entire "Stade de Suisse" PV-installation and the 16 minute steep slope terrain flight track of the 20 000 sqm PV-installation at "Mont Soleil" will be complemented by IR-mappings of retrofitted skyscraper PV-envelope buildings and high-elevation PV-installations in the Swiss Alps (Fig. 6).

Figure 6: Retrofitted skyscraper, Zurich, Switzerland (left). Photo: sharp.ch. PV-installation at Jungfraujoch (3 454 m asl) in the Swiss Alps (right). Photo: BFH-TI.

All thermal images will be incorporated into a PV LAB data bank containing visuals showing typical defects of PV-modules. A software will be developed to automate the localisation of defects in large PV-installations.

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