5BV.2.34 Drone-Based Assessment of Cleaning Effects on PV Installations

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A new unmanned aerial drone vehicle was developed and built at the Photovoltaic Laboratory (PV LAB) at Bern University of Applied Sciences BFH, Switzerland. Application to PV systems operated by the PV LAB reveals that real efficiency advantages are offered by drone-based inspection of (large) PV installations.
Here, we investigate how the thermal imaging drone system can also help to identify and quantify the energy yield losses due to environmental pollution.

The PV LAB IR-multicopter drone

The PV LAB IR-multicopter drone (Fig. 1) carries an infrared camera that records a thermal imaging video and a digital camera for comparison shots. Using this combination, PV module surfaces can quickly be monitored and defects easily determined and located.

Fig. 1: PV LAB IR-multicopter drone; the take-off weight is about 7.5 kg.

Drone-based inspection of PV systems

Inspection of (large) PV installations in the network of Swiss PV systems (operated by the PV LAB) shows that the IR-multicopter drone can detect power losses of about 5 Wp. Fig. 2 displays a IR video capture and a close-up thermal image of a defective Siemens M55 module.

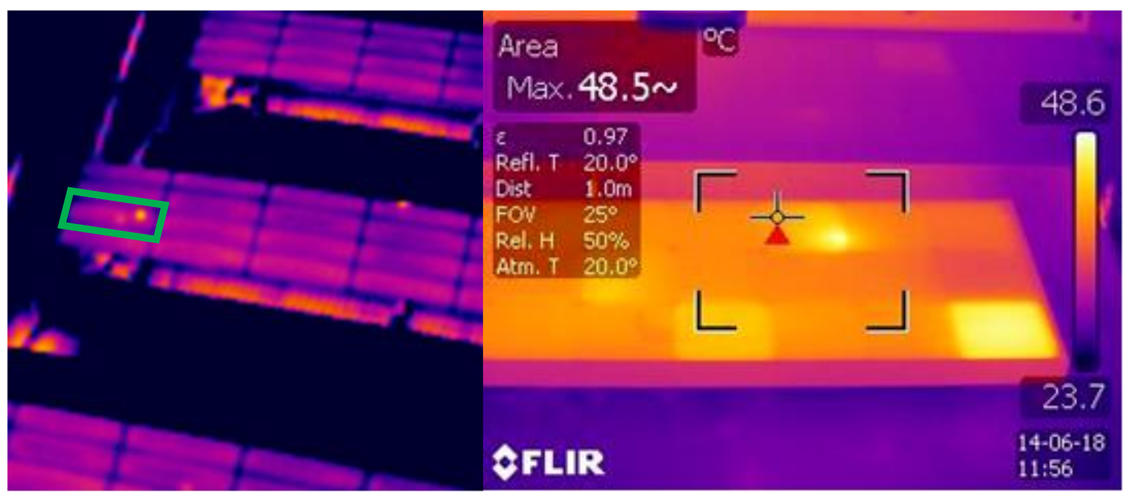

Fig 2: IR video capture, magnified (left) and close-up of marked module (right).

The power loss (of about 20%) of the module in Fig. 2 is illustrated below.

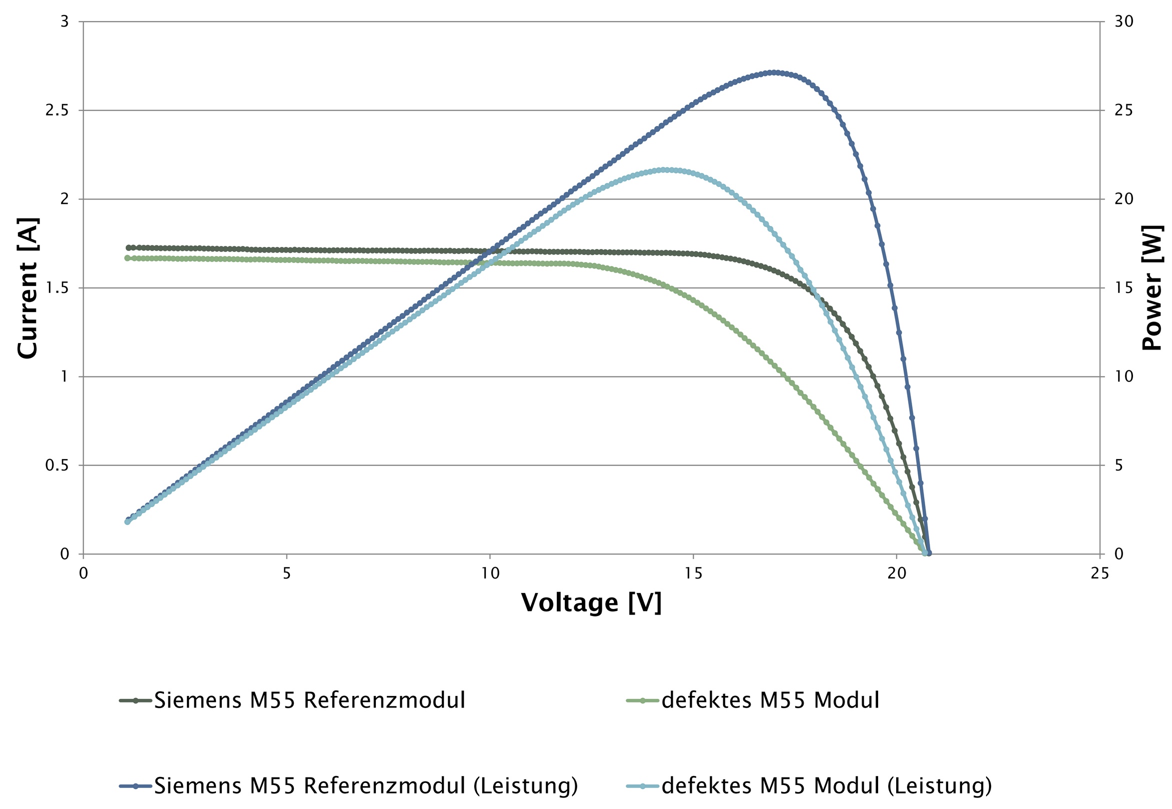

Fig. 3: Characteristics of the defective module (marked Siemens M55 module, Fig. 2).

Energy yield gains from cleaning

Regular cleaning of the PV module surfaces increases the electric energy output. Long-term effects of PV module surface cleaning are displayed in Fig. 4. The PV installation is a 50 kWp roof-top system cleaned every four years since the 1990s, resulting in a yield gain of 5-8%.

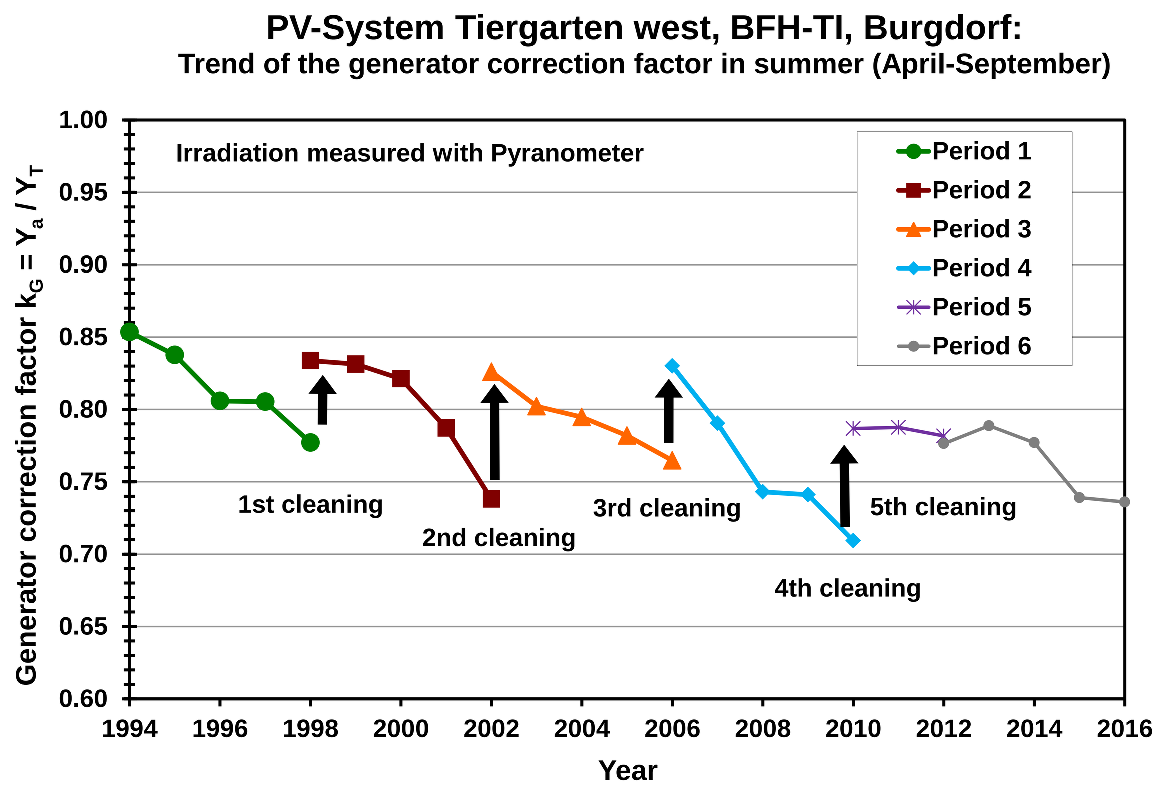

Fig. 4: Energy yield increase (1994-2016) of the PV installation at the PV LAB due to cleaning.

The values in Fig. 4 show the "generator correction factor" k_G, representing the ratio of the actual yield to the theoretical yield. k_G is formed by dividing the "array yield" (Y_A) by the "temperature-corrected radiation yield" (Y_T) in Formula 1.

$$k_G = \frac{Y_A}{Y_T} = \frac{Array - yield}{temp. - corrected\ radiation\ yield}$$

Formula 1: Calculation of k_G

The k_G values were also calculated for the "Stade de Suisse" football stadium in Bern, Switzerland (Table 1).

The "Stade de Suisse" football stadium in Bern has a total capacity of 1347 kWp. In summer 2015, the entire module surface was cleaned after 5 and 8 years of operations, respectively. Using the thermal images from the PV LAB IR-multicopter drone and additional power measurements, the K_G-values were determined. Fig. 5 shows the KG-values of the "Stade the Suisse" PV installation over time. Table 1 indicates energy yield gains between 4-9% due to cleaning the module surfaces in summer 2015 (Table 1).

Subsystems	Increase in %	Notes / since year
BI1	4.0 → ~4	2nd cleaning 10/15
BI2	6.4 → ~6	2nd cleaning 10/15
CI1	5.7 → ~6	2nd cleaning 10/15
CI2	4.3 → ~4	2nd cleaning 10/15
CI3	4.3 → ~4	2nd cleaning 10/15
DI1	5.6 → ~6	2nd cleaning 10/15
DI2	6.4 → ~6	2nd cleaning 10/15
E1 (AA1)	6.4 → ~6	1st cleaning 07/15
E2 (AA2)	8.5 → ~9	1st cleaning 07/15
F1 (DA1)	7.8 → ~8	1st cleaning 07/15
F2 (DA2)	7.5 → ~8	1st cleaning 07/15
Total	**6.2 → ~6**	

Table 1: Energy yield gains at the "Stade de Suisse" after cleaning the PV modules.

Cleaning the PV modules after 5 years of operation increased the energy yield by 4-5% (module inclination of 7 degrees). Cleaning the PV modules after 8 years of operation increased the energy yield by 6-9% (module inclination of 20.5).

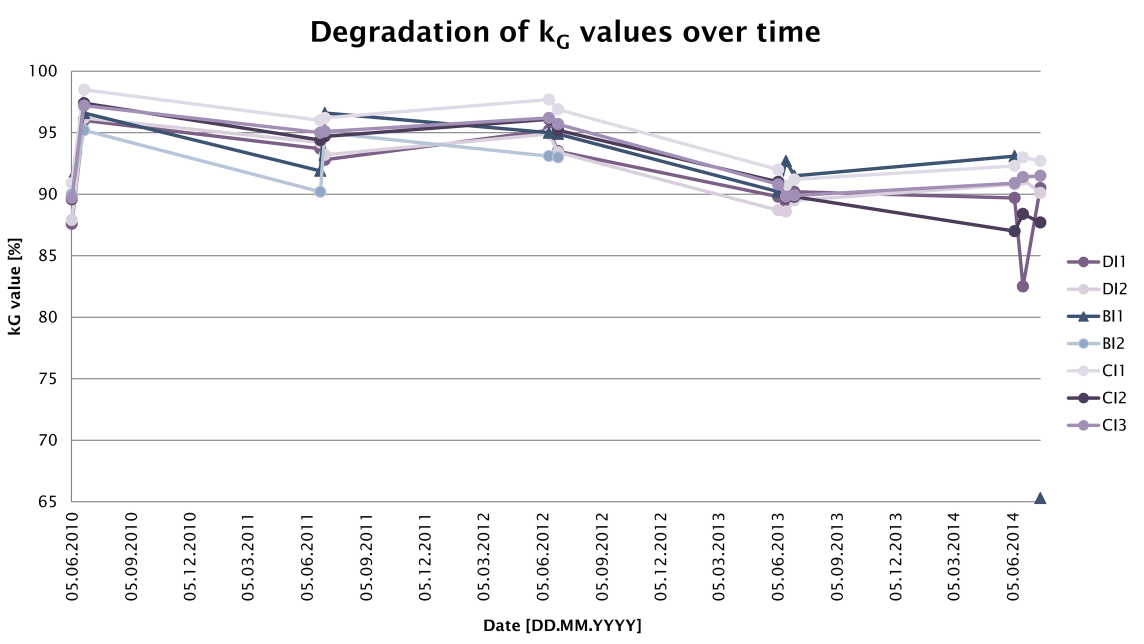

Fig. 5: k_G values (2010-14) of the "Stade de Suisse".

Conclusions

Thermal images provided by drones are highly efficient for the identification of (pollution-related) "hot spots" and power losses in PV modules. The quantification of homogeneous contamination effects and related changes in energy yield must, however, rely on measurements.

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