Unmanned Aerial Vehicle for Infrared Inspection of Photovoltaic Modules

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IR inspection of PV modules by means of UAV and any activity with UAV is not always possible, or the use is limited to specific infrastructures (airport, military zone, helicopter rescue runway, natural parks, etc.) where the flight is prohibited or restricted.

Fig. 1. EU member states

Table 1. Constraints and limitations for geographical areas in most of the EU member states

<table>
<thead>
<tr>
<th>Country</th>
<th>Method</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>TEST</td>
<td>5.5 km from ABP</td>
</tr>
<tr>
<td>Belgium</td>
<td>TEST</td>
<td>3 km from ABP and 10 km from airport</td>
</tr>
<tr>
<td>France</td>
<td>TEST</td>
<td>1 km from AOP</td>
</tr>
<tr>
<td>Denmark</td>
<td>TEST</td>
<td>3.3 km from ABP</td>
</tr>
<tr>
<td>Greece</td>
<td>TEST</td>
<td>5 km from ABP and 10 km from airport</td>
</tr>
<tr>
<td>Estonia</td>
<td>TEST</td>
<td>2 km from AOP</td>
</tr>
<tr>
<td>Ireland</td>
<td>TEST</td>
<td>2 km from AOP</td>
</tr>
<tr>
<td>Italy</td>
<td>TEST</td>
<td>3 km from ABP</td>
</tr>
<tr>
<td>Poland</td>
<td>TEST</td>
<td>3 km from AOP</td>
</tr>
<tr>
<td>Sweden</td>
<td>TEST</td>
<td>3 km from AOP</td>
</tr>
</tbody>
</table>

Fig. 2. Italy map from d-flight.tv colored restricted areas

Hardware-software system

It represents a logic scheme that describes the operation of a complete system for inspection of PV modules by means of UAV and IR camera. The main part is the hub that allows to share data among all the devices.

Hub receives IR images from UAV and environment parameters from the meteorological station. To automate the calculations of some parameters of different areas of the radiometric map, a cloud-based software is necessary.

We suggest software DSS that downloads IR image from hub (1), process image (2), and uploads the results (4) on hub. The data are stored into a database (5) to track the thermal history of each PV module. After DSS calculated the main parameters of the PV module, a certified technician can assume the final decision about it.

Criticalities and suggestions

Defects in PV cells, and dust on PV modules reduce the energy produced by a PV plant. Focusing attention only on the defects in the PV cells, it results that they appear as overtemperature, i.e., a temperature higher than the temperature of a correct operation. This parameter is specific for any module and is called Nominal Operating Cell Temperature (NOCT).

This value depends on the environmental conditions; therefore, it is defined in these conditions: solar irradiation, G, equal to 800 W/m², air temperature, T₀, equal to 20 °C, wind speed equal to 1 m/s.

It is noted that these conditions are different from the Standard Test Conditions (STC), i.e., G = 1000 W/m² and cell temperature Tc = 25 °C, which are used to specify all the other parameters in the manufacturer datasheets [16]. When a laboratory test is performed, it is possible to set the desired values of solar radiation and air temperature, and to the cell temperature with the NOCT value. Instead, when an outdoor IR analysis is performed, the values of solar radiation and air temperature are different from the NOCT.

In this case, it needs to normalize the NOCT to the equivalent value in the actual conditions. In new PV module, the NOCT is substituted by the Nominal Module Operating Temperature (NMOT). In any case, the equivalent value, for example eNMOT, can be calculated as [17]:

\[
eNMOT = T_a + \frac{NMOT - 800}{g} \cdot 800
\]

Fig. 3. Limitation for activities in open category

Specific (Authorization is mandatory)

- One of the requirements for Open category is not met;
- The competent authority shall issue an operational authorization if the operational risks are adequately mitigated;
- The competent authority specifies operational authorization concerns;
- IFUP operator submit a declaration that operation is compatible with a fixed standard scenario, authorization is not required.

Fig. 4. Limitation for activities in specific category

Certified (Certification is mandatory)

Operation is conducted in one of the following conditions:

- It is over assemblies of people;
- It involves the transport of goods;
- It involves the carriage of dangerous goods, that may result in high risk for third parties in case of accident.

Fig. 5. Limitation for activities in specific category

References