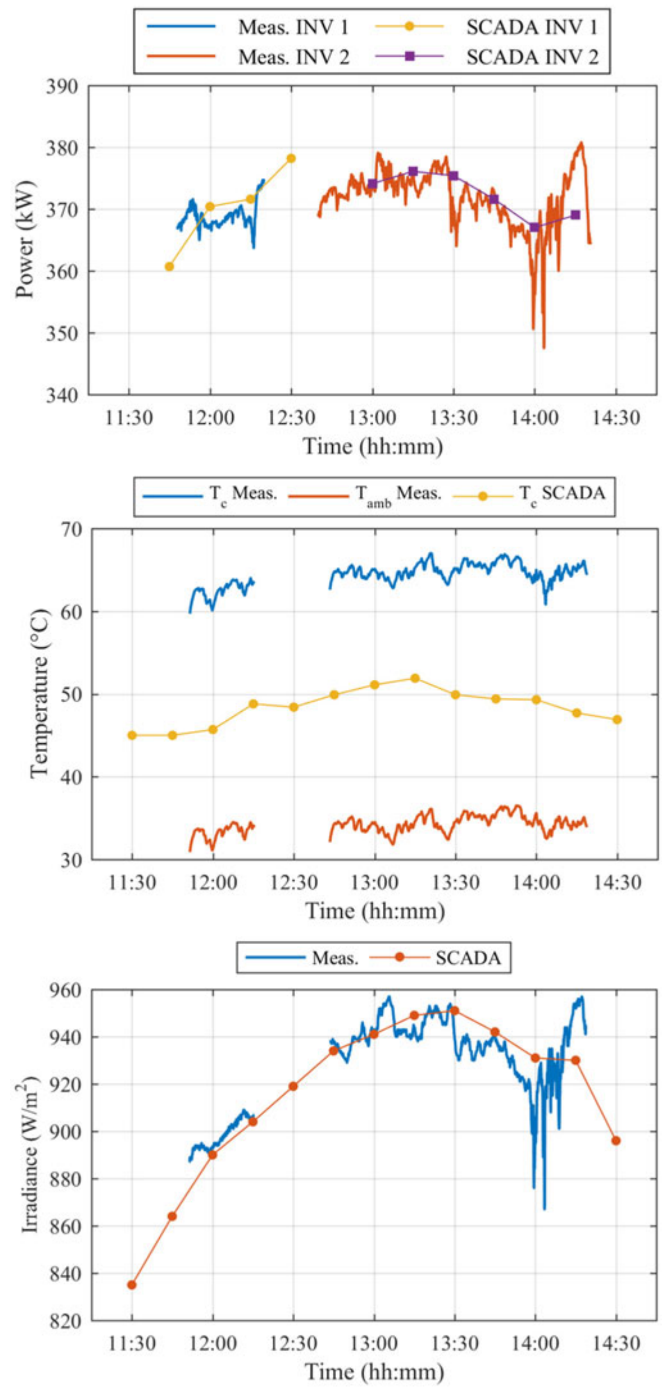

Fig. 9. Temperature, irradiance, and power comparison between data recorded by SCADA and measurement (Meas.) in plant D.

spot does not always identify a specific defect but often it is related or caused by other failures listed in Table III.

Early fault diagnosis represents a key factor in O&M activity, but if we imagine to repeat more flights per year on the same plant the cost of the system becomes an issue. However, for large plants, especially on roof plants, the UAV system represents a real effective alternative. A complete manned IR inspection of 1 MW plant may require 1–2 days, but with a comparable cost it is possible to fully inspect the same plant in just 1–2 h, having a more complete information and a complete picture of the defects' origin thanks to the multiple sensors use.

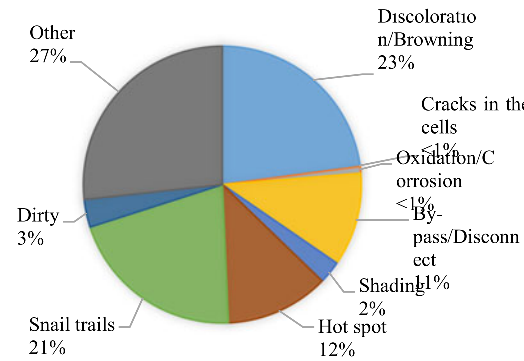

Fig. 10. Circle chart related to the module defects in the 5 plants (over the total number of failures).

With respect to the percentage of failures at module level found in this flight campaign (see Fig. 10), it is quite valuable comparing our findings with the recent literature even if not trivial and made on heterogeneous samples. In [19], both failure rates due to customer complaints in the first two years after delivery and based on a field study of many manufacturers in the midlife are reported. The rates are given relative to the total number of failures such as in our study, and show a wide range of occurrences, often with different classification criteria: for example, defect cell interconnects are around 10%, j-box and cables around 10–20%, glass failures 10–30% depending on the plant age and means of detection. In [20], a physical model for degradation and reliability is validated on a large statistical data set, confirming that some studies do not distinguish for example corrosion damage from fatigue damage; however, more than 60% of returns is attributed in this case to cell-interconnection issues, considering modules that are aged less than 10 years. Kurtz *et al*. [21] discuss the degradation mechanisms depending on both technology and climate zones, as well as how they generally affect differently current and voltage giving average rates in terms of %/year with no distinction based on the nature of defects. Finally, [22] reports a project report on PV plant risk assessment, finding that among the overall common failures, glass breakage, ethylene-vinyl acetate discoloration, and defective backsheets bear a higher level of economic impact on O&M.

It is important to notice that UAV technology is too young to make available a large data set if compared for example with customer care data set. Even if the failure rates reported in this study are referred to ordinary or preventive maintenance in three of the five plants, some similarities with the literature can be found for the by-pass (j-box), cell, and hot-spot failures, while in our campaign we did not find high rate of glass breakage. Finally, a detailed comparison was not easy because of the different means of failure classification among the studies.

V. Conclusion

One of the most promising inspection methods for PV energy plants is the use of unmanned technology. Many modules installed in the recent past show a various range of defects which compromise their performance. This paper provides an overview