USES4

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Project description

In recent years new trends and challenges are involving photovoltaic (PV) power sector due to a dramatic change of the market. Plant monitoring and O&M is becoming a crucial point in this field: plant owners and operators are requiring higher accuracy and lower costs in the maintenance operations to keep at top the performance of the plant during its whole lifetime. PV modules installed in the last decade recently have shown quite a wide range of defects able to sensibly compromise the performance of the plant. Standard monitoring techniques are based on a completely manual systems where operators take pictures of the PV plant and identify potential defects generally on a visual approach. These procedures have many drawbacks, for example the very long time required, the need of an expert operator which often means subjectivity and the impossibility to perform on most of the roof-top plants. Moreover, this monitoring reduction in the power production not assuring a decision-making preventive strategy.

This project is aimed to integrate a fast monitoring system, based on the Unmanned Aerial Vehicles technology with an appropriate sensor suite, combined to an economical power site analysis. This combination will lead to an optimized technique: while the novelties in the monitoring system will reduce the monitoring time and will increase the effectiveness of acquired information, the economic analysis will find the optimal scheduling of the monitoring and the optimal maintenance strategy in terms of return on investments.
The use of Unmanned Aerial Vehicles helps to speed up the operation and include a new class of plants (namely the roof-top plants) in the monitoring and O&M PV market. This system produces a huge amount of data that can be successfully processed with computational techniques: the results of the project is a complete map of the plant where the defected modules can be easily found with respect to their critical impact on the energy production.
In order to improve the overall system efficiency, a decision-making process has been investigated as well: in particular, an optimized support system can help the operator to identify optimal maintenance strategies, thus it can be applied to a large plant portfolio leading to a growth of the assets' profitability. A potential extension to other Renewable Energy power plants can enhance the impact of the proposed system to other stakeholders like large Energy Companies, Insurances and Investment Funds.

Key Words

Photovoltaics-Monitoring, Photovoltaics-Maintenance, Drone-Inspection, Thermography, Process-Optimization


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Innovative Unmanned Systems for Supporting Efficient
and Effective PV Plant Maintenance Planning
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Team description by skill

Giulio Cantoro: his main activities included market research (photovoltaics in Europe, stakeholders' needs and interaction), state of the art research (photovoltaic plant monitoring), maintenance optimization and forecast model, graphic user interface, business model.

Raffaele Guido: his main activities included market research (UAV applications, photovoltaics in Italy), state of the art research (UAVs in plant monitoring, alternatives to thermography), optimal maintenance intervention algorithm, maintenance forecast optimization algorithm.

Andrea Milanta: his main activities included market research (photovoltaics in the world), state of the art research (image processing for photovoltaic thermal images), image processing, defect recognition.

Maurizio Valesani: his main activities included market research (UAV applications, stakeholders' needs and interaction), state of the art research (UAVs in plant monitoring, alternatives to thermography), picture-sorting algorithm, digital map assembly.

Marco Villani: his main activities included market research (UAV applications, stakeholders' needs and interaction), state of the art research (module defect recognition, defect impact on module performance), module degradation model, automatic report generation.

Abstract

The photovoltaic industry is one of the fastest growing worldwide, also thanks to climate change policies. The same holds true for Italy, which aims at a relevant increase in installed capacity by 2030. Due to its topography, though, this increase must be accompanied by an improvement of plant efficiency. However, residues of the incentives system of 2010-2013 and the inherent complexity of maintenance, together with its over-reliance on manual, time-consuming procedures, often result in plants been neglected with a considerable performance loss, which hinders the needed efficiency increase.

USES4 project sets its root within this need to increase the efficiency level of PV plants and aims at exploiting the industry potential to determine a business opportunity. The route chosen aims at the development of a service based on the automation of inspection, maintenance, data analysis, and decision-making procedures in PV plants, to streamline them and reduce their cost as well as improve plant energy production.

By automatically generating an interactive, digital map of a plant from pictures taken by the drone during an inspection according to a set of ad-hoc defined guidelines, with detailed information on the health status of each single module, and providing a technical report including a set of suggestions on the optimal maintenance intervention based on the maximization of the production and minimization of costs, USES4 team hopes to introduce a drastic innovation in the photo-voltaic maintenance sector. The designed tool has the potentiality to modify the future scenario by optimizing present procedures, fostering a change in maintenance practices leading to a minimization of the profit loss in plant management.

Understanding the problem

The photo-voltaic industry is one of the fastest growing worldwide. With $161 billion of investment (2016) and a CAGR (Compound Average Growth Rate) of over 40%, it holds the top spot in the renewable energy market. Political initiatives aimed at reducing emission and limit fossil fuel consumption are fostering the sector. Focusing on home turf, Italy's photovoltaic market is just starting to pick-up after a crisis period following the end of the incentives in 2013. At the end of 2017, 19.67 GW were installed in Italy, a figure expected to grow. SEN's (Servizio Energetico Nazionale) objectives for 2030 aim at a yearly PV energy production of 72 TWh and depict a road map that foresees new installations for 33 GW, the re-powering of already installed plants for 2 GW and the revamping of the available 20 GW installed.

This scenario increases the pressure on O&M operators for increasing monitoring and maintenance efficiency. However, residues of the incentives system and the inherent complexity of maintenance often result in plants been neglected with a considerable performance loss. In this context, a need for optimized monitoring and maintenance is becoming apparent. Plant owners and asset managers are looking for a detailed appraisal of the status of a plant, to optimize its production and the profit it generates or to maximize its market value for a transaction. Respectively, plant buyers are looking for an objective representation of the health of a plant before deciding to invest in it. The two categories are linked by O&M operators, in charge of assessing the plants and guaranteeing an agreed upon level of performance. Another key role is played by insurance companies, as circa 25% of a system's annual operating cost consists of premiums, ranging from 0.25% to 0.5% of the total installed cost. Finally, authorities complete the overall picture, source of standards and regulations, as well as interested in statistical data on the performance of installed facilities and the technological progress to define incentives.

All these actors share the need of a quick, affordable, and objective representation of the status of a plant, and would all benefit from an optimization of maintenance intervention aimed at improving plant performance. Current market offers however are still based on manual intervention and cannot provide time and cost-effective solutions, while maintenance interventions are often economically suboptimal.

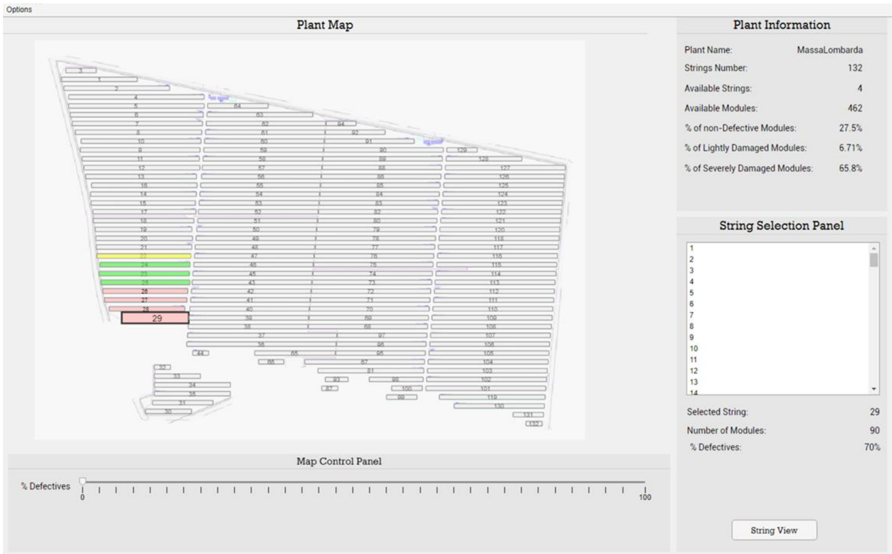
Exploring the opportunities

Having identified the market need for an improvement of the overall quality and efficiency of plant monitoring and maintenance planning, different routes have been considered to provide a suitable product or service to the involved stakeholders. Due to the partnership with a drone manufacturer already participating in photovoltaic monitoring and the prevalence of aerospace engineers in the team, efforts were initially focused on understanding whether it was possible to optimize the flight procedure. Automating the flight seemed at first a very promising alternative, with interesting margins for improvement. However, after having spectated an on-the-field example of monitoring procedures, it became apparent how the benefits from a pilot-less flight would have been negligible due to the outstanding inefficiencies hindering the process. Leaving flight automation as a possible future development, focus was shifted to the optimization of existing procedures and the automatic generation of an interactive digital map of the plant, to eliminate the need for manual intervention when unnecessary and minimizing down-times, while at the same time improving output quality.

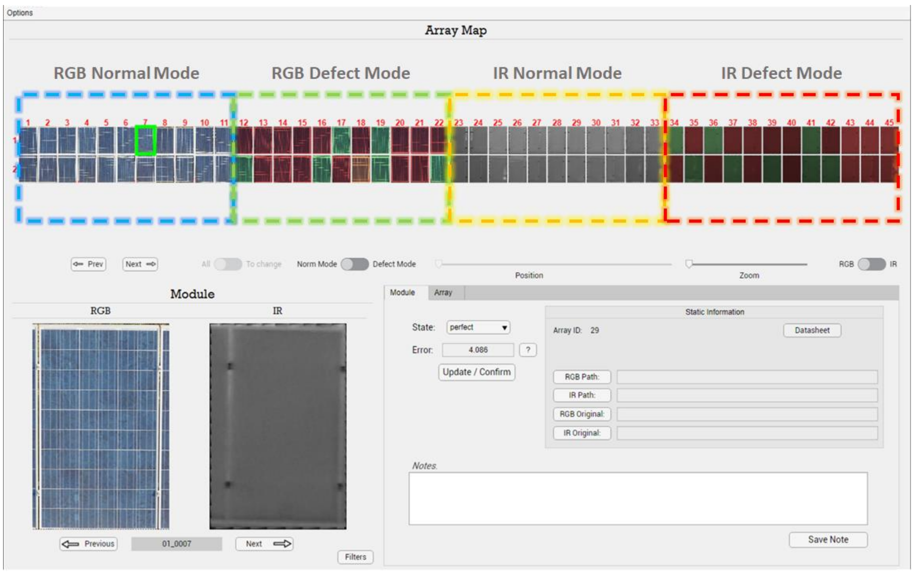
Moreover, during the concept development phase, a critical point that was faced was the selection of the scope of the service, as two main alternatives presented themselves. On the one hand, limiting the service to the generation of a digital map of a plant would have tackled the need to improve monitoring performance, and it would have meant a stronger focus on defect recognition and classification; however, maintenance planning would have been neglected and left to its underperforming state. On the other had, partially sacrificing output quality in favor of the preliminary design of a maintenance optimization tool would have tackled both the identified issues, and it would have shown the real potentiality of the devised idea. While the first route would have allowed to present a complete, market-ready product, the final decision fell on the most ambitious alternative, due to its pervasive innovative aspect and its higher appeal to different stakeholders in the field.

Generating a solution

The outcome of the project aims at alleviating the two most prominent critical aspects identified within the PV monitoring and maintenance subsector: the slowness and low accuracy of manual data gathering and analysis, and the lack of detailed information on the health status of a plant to be used to make informed decisions when planning maintenance operations. Thus, the first step of the service devised by the team consists of an automatic management and sorting of the raw images, both visible and infrared, captured by the drone. Then, data associated to the pictures are further processed to unequivocally identify each module. Defect recognition is automatically performed by an AI algorithm, the precision of which can improve the more data it collects. Then, a digital map of the plant is presented to the user, who can easily access information of each panel in the plant, from its position to its defects.



Main window of the Visualization tool.



Array window with different display alternatives combined.

To make sure the quality of the input images is consistent and sufficient for the software to properly operate, a set of dedicated flight guidelines for drone pilots has been conceived. The goal, however, is to improve the robustness of the code, so as to make it possible to relax said guidelines and limit the service reliance on drone operators. Gathered information is then transmitted to a predictive and evaluative algorithm, tasked to estimate the general status of the plant, suggest the optimal maintenance intervention and predict the optimal moment for the next inspection, with a prediction of the expected magnitude of the intervention itself. Thus, maintenance planning is enhanced, as it can be based on detailed information on the health of each module. Moreover, maintenance operators are provided with more information on their task, which further streamlines their job and limits mistakes by reducing uncertainty. Finally, customized reports are produced, ranging from a purely technical description of the status of the plant to a set of operative guidelines for maintenance optimization, or, as a future development, a detailed financial evaluation of the asset.

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