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Simplified method for evaluating the effects of dust and aging on photovoltaic panels

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ABSTRACT

As well known, maximizing the efficiency of photovoltaic plants is key to increase their competitiveness. Aging and presence of dust on the panel surface strongly reduces the energy production, which results in significant economic loss. In this paper a simplified method for evaluating the impact of both aging and dust deposition will be presented. The proposed approach allows distinguishing the losses of energy production due to aging of the photovoltaic panels from the losses due to the presence of dust on the surface.

The method can be implemented using information provided by a public weather station or using a reference panel.

In this way a suitable and cost effective maintenance strategy can be implemented. In the paper the description of the method and its validation are reported.

1. Introduction

It is well known that the presence of dust on the surface of a PV modules have significant impact on their efficiency [1–4]. Then, the consequent reduction in energy production has a non-negligible effect on the incomes [5].

Different environmental and weather conditions can influence dust deposition as, for instance, volcanic eruptions, sand, pollution, rain, wind, etc. [3,6–10]. The presence of dust and sand produces a negative impact on PV performance due to the fact that dust is able to block incident photons which are not able to reaching the PV cells. In [6] the effect of dust particles accumulation has been modeled as a reduction of the useful area of the PV module. In [1,2,10–12] dust accumulation is taken into account and the relative effects in terms of loss in effective availability irradiance have been discussed.

In any case the most important effect of the presence of dust is a reduction of the PV performances in term of energy production. The reduction can be evaluated by considering, in the same conditions, the difference between the actual power production of the panel and that it would be produced at the beginning of its operative life. This can be performed by considering a model of the panel, which has to be identified as soon as it has been installed [13,14]. In addition to the presence of dust, also the aging of the PV cells have an impact in a reduction of the energy production. So, in order to plan an effective maintenance activity, it is fundamental to distinguish the aforementioned two phenomena [5]. In [2] the authors propose a

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solution based on a statistical approach in which a reference panel is cleaned periodically, so that its energy production is just affected by aging. In this proposal the most part of PV panels work at the maximum power point (MPP). Therefore, the model of the PV panel can be replaced by a simple expression which predicts the maximum power in each environmental condition, namely for a given solar irradiance level and cell temperature. This condition allows simplifying both the identification of the model and the prediction of the energy production. In [15], authors propose a possible implementation starting from the data acquired during the normal operation of the reference panel. It is clear that this approach requires the knowledge of the solar radiation [16]. However, it is important to underline that pyranometers, used for solar radiation measurement, are expensive and periodic cleaning and maintenance of these instruments are mandatory, thus resulting in high cost. However, in [13,15] authors investigate the possibility to avoid the employment of a dedicated radiometer. In fact, during sunny days the solar irradiance level on a PV module can be inferred using the measurements provided by a third-part weather station.

In Section 2 the proposed method will be presented. The method is based on an MPP model, which will be presented in the following Section 3. In Section 4 the issue related to the use of data provided by public weather station will be discussed. In Section 5 the experimental setup used for the validation of the model will be presented. In Section 6 the experimental validation is presented considering data provided both by local sensors and public weather station. Conclusions are finally given in Section 7.

2. Proposed method

Regarding requirements presented in the previous section, in this paper the authors propose the new method verifying the panel degradation caused by dust and aging. It reduces costs related to the periodic measurement operations (i.e., the periodic human actions on the monitoring apparatus).

To decrease the maintenance costs due to the irradiance measurement and periodic model updates, the authors introduce a new approach based on the model evaluating the maximum power point (MPP).

This model allows estimating the energy production using either a public weather station or a local radiometer data. The use of data provided by public weather station allows furthering reducing the costs of the maintenance.

The method is based on the idea that energy produced by a PV reference panel can be inferred to the energy produced by a PV plant. This assumption is true if two conditions are satisfied:

- The reference PV panel belongs to the same production batch of the panels installed in the PV plant; in this way, it can be considered statistically representative of the batch itself [2].
- An electric model of the PV panel able to predict in each conditions of solar radiation and PV panel temperature must be available.

The method based on the previous assumptions allows reaching two important aims:

- The first one is monitoring the energy losses due to the dust thus allowing to evaluate the time to maintenance (in this case we refer to cleaning activity) of the PV plant.
- The second one is represented by the analysis of the aging.

These aims can be reached by comparing the actual energy production of the reference panel with that estimated on the base of its MPP model.

The reference PV panel is modeled by means of four parameters. Their evaluation does not require additional human resources and can be done in any environmental conditions. Moreover the reference panel has not to be put in out of service.

The model parameter estimation is performed at the PV plant installation time, thus defining the reference condition (aging zero and clean surface). Now comparing the actual energy production with the estimated one, it is possible to evaluate the production reduction. On the base of this evaluation it is possible to plan maintenance activity as shown in [5].

After having cleaned the panels the effect of aging can be evaluated always by means of a comparison between the actual and estimated production. At this point the model parameters can be easily recomputed (in any environmental conditions) thus to define the new reference point for the evaluation of the dust effects.

The trend of the model parameters along time is a clear indicator of the panel degradation due to the aging.

3. Prediction of the maximum power

As aforementioned, the presence of dust, the aging process and degradation of the cells leads to a reduction of the power generated by a PV panel for given electrical load and environmental conditions [1,2,15–17]. Therefore, the difference between the actual energy production and the energy that the panel would have produced at the beginning of its operating life for the same solar radiation and panel temperature represents a robust indicator of a malfunction. In [13] authors propose a possible implementation based on a model of the photovoltaic panel. Its parameters have to be estimated just after it has been installed, so that the model can be used to predict the power which the PV module should have produced if it were not affected by dust and aging. The model requires the knowledge of temperature of the cells, which can be estimated by measuring the temperature of a point of the module which has to be as close as possible to the cells [18,19]. Furthermore, the model requires the solar radiation G, which in sunny days can be easily estimated with good accuracy from the data provided by weather stations following the procedure descripted in [13] and reported in the next section. Finally, in order to predict the power output, and therefore to estimate the energy production, the model also needs the V–I curve of the load connected to the panel. In general,