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The effect of soiling on energy production for large-scale photovoltaic plants

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Abstract

This work aims to evaluate the effect of soiling on energy production for large-scale ground mounted photovoltaic plants in the countryside of southern Italy. Since the effect of pollution can seriously compromise the yield of solar parks, the results obtained in this study can help the operation and maintenance responsible in choosing the proper washing schedule and method for their plants and avoid wasting money. In order to determine the losses due to the dirt accumulated on photovoltaic modules, the performances at Standard Test Conditions (STC – Irradiance: 1000 W/m^2; Cell temperature: 25 °C; Solar spectrum: AM 1.5) of two 1 MW$_p$ solar parks before and after a complete clean-up of their photovoltaic modules have been compared. The performances at STC of the two plants have been determined by using a well-known regression model that accepts as an input two climate data (the in-plane global irradiance and the photovoltaic module temperature), while the output results in one electrical parameter (the produced power). A regression model has been preferred to a common performance ratio analysis because this latter is too much influenced by the seasonal variation in temperature and by the plant availability. The results presented in this work show that both the soil type and the washing technique influence the losses due to the pollution. A 6.9% of losses for the plant built on a sandy soil and a 1.1% for the one built on a more compact soil have been found. Finally, these results have been used in order to compare the washing costs with the incomings due to the performance improvement.
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Keywords: Large-scale photovoltaic plant; Soiling; Pollution; Performance; Produced energy

1. Introduction

With reference to Fig. 1, during the last 4 years the Italian photovoltaic market has been growing exponentially following a tendency already widely seen especially in Germany. This impressive growth has been driven by the introduction, at the end of 2005, of the feed in tariff mechanism which ensures satisfactory payback times and investment productivities to the investors. During 2009, the Italian photovoltaic market has been the second one for installed power all around the world.

As reported in Table 1, during 2009 the Italian installed power has grown at a rate of 165% with respect to 2008. Since the major part of the Italian market (69.5%) is focused on large size plants, this work investigates the operations of two 1 MW$_p$ photovoltaic systems.

The accumulation of dirt on solar panels ("soiling") can have a significant impact on the performance of PV systems. Much of the information available is applicable only

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Nomenclature

AC	alternating current	*PV*	photovoltaic
A, *B*, *C*, *D*	polynomial coefficients	*STC*	standard test conditions (Irradiance: 1000 W/m^2; Cell temperature: 25 °C Solar spectrum: AM 1.5)
CAN	controller area network	T_{mod}	photovoltaic module temperature (°C)
DC	direct current	V_{DC}	direct current bus voltage (V)
H_i	in-plane global solar irradiance (W/m^2)		
I_{DC}	current produced by the photovoltaic strings (A)		
MPPT	maximum power point tracker		

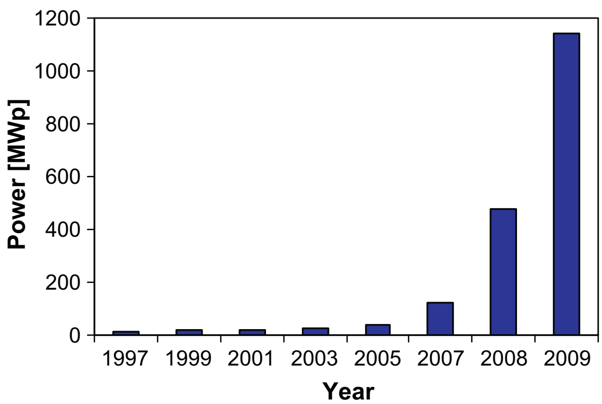

Fig. 1. Italian overall installed PV power.

Table 1
Italian installed PV power for power classes during years 2008 and 2009.

Power	2008 MW_p	2009 MW_p	%	$\Delta_{2008–2009}$
(1–3) kW_p	40.6	86.7	7.5	+113%
(3–20) kW_p	112.7	262.9	23.0	+133%
>20 kW_p	278.2	792.7	69.5	+185%
Total	431.5	1142.3	100	+165%

to the specific location in which the testing was conducted (Kimber et al., 2006). The most impressive result found in literature shows that about 8–10% of the power loss registered can be removed by cleaning the arrays (Haeberlin and Graf, 1998). Soiling losses in thermal solar collectors were studied by Biryukov et al. (Biryukov et al., 1999) and by Garg (Garg, 1974). The effect of soiling in concentrator photovoltaics was studied recently (M. Vivar et al., 2010)."

This work deals with the effect of soiling on the energy production of big solar parks installed in the countryside of southern Italy. Does the dirt on PV modules have an impact on their capacity to produce energy in this region? If yes, how much does the pollution decrease their efficiency? Answers to these questions are essential both to predict PV plants performance (Hammond et al., 1997) and to calculate a reasonable cash flow analysis (Lughi et al., 2008). This latter is a fundamental issue in a country like Italy where, as incentives to the investment in grid connected photovoltaic plants are given through a feed in tariff mechanism, the produced energy plays a fundamental role because of its strong relation with the payback (PB) time and the investment productivity (IP) (Mellit and Massi Pavan, 2010a). Moreover, correct estimates of losses due to the pollution effect on a given PV plant also enable technicians to provide reliable yield calculations that are required for developing dispatch plans. Indeed, these latter have to be provided in order to well integrate the grid connected photovoltaic plants into the new distributed generation concept (Mellit and Massi Pavan, 2010b).

How the pollution affects the energy yield is the question which this study aims to answer. Consequently this research monitored the operations of two photovoltaic plants installed in Puglia before and after a complete clean-up of their PV modules. It should be noted that Puglia represents – both in 2008 with 53 MW_p and in 2009 with 214 MW_p installed – the first region in Italy for PV installations.

In order to predict the power produced at Standard Test Conditions (Irradiance: 1000 W/m^2; Cell temperature: 25 °C; Solar spectrum: AM 1.5, hereafter briefly STC) before and after the clean-up process, a regression model to represent the behaviors of the two PV plants has been used. The comparison between the power rates before and after that the PV modules have been washed is related to the soiling effect on the PV plants performances.

This article is organized as follows: the next section gives a short description of the two PV plants under study. The database used is presented in Section 3. The polynomial regression model used for determining the behaviors of the two systems is discussed in Section 4. Results and discussion are presented in Section 5 and, finally, conclusions are given in Section 6.

2. Photovoltaic plants description

The two solar parks under study have been ground mounted with the use of a certain number of rammed poles. The PV plants are connected to the distribution grid and implement a centralized conversion (Massi Pavan et al., 2007) since each of the two inverters has one MPPT. The low voltage inverter outputs are raised to 20 kV via a transformer allowing the connection with the medium voltage electrical grid. Climate and electrical data are stored in

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