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Article

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Experimental investigation of soiling impact on grid connected PV power

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Abstract

Algeria has large territory which is around 2,382 million km with an average solar power of 2650 kWh/m^2/year on more than 80 % of the total surface of country. Back in 2015, the Algerian government has adopted a program for electricity production with an objective to insert 13GW of photovoltaic (PV) systems, which corresponds to an estimated modules area of 90 km^2 distributed over the national territory. The PV systems choice is justified by the availability of a great solar potential. Nonetheless, the Sahara regions are characterized by frequent sandstorms. But the Algerian Northern regions are characterized by exhaust emissions of carbon particles. The main objective of our study is to show the impact of the soil on grid connected PV performance in coastal regions. Hence, experiments have been conducted on clean and dirty PV modules glazing in natural conditions to determine the electrical characteristics. It was found, that the dirt can significantly minimize the power production during the day, for an exposure period of one month and half after the last cleaning. It is very important to indicate that, this experimental investigation can help forecasting the PV generator energy production by taking into account of dirt effects.

Peer-review under responsibility of the scientific committee of the 6th International Conference on Energy and Environment Research, ICEER 2019.

Keywords: Grid connected PV system; Soiling effects; PV generator performance

1. Introduction

Currently about 344 MW$_p$ of grid connected PV systems [1] which corresponds approximately to 2.34 km^2 of module surfaces are distributed over the national territory of Algerian area (Fig. 1). Nonetheless, the winds restless the mixture particles of dust and black carbon, with time these particles are deposited on the surfaces.

The soiling accumulation on photovoltaic modules glazing affects the energy productivity, see Fig. 2. This natural phenomenon prevents the electromagnetic waves absorption by the semiconductor material [2], which consequently decreases the grid connected PV system yield.

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Nomenclature

STC	standard test condition 25 °C, 1000 W/m^2, AM. = 1.5
P_p	peak power at STC (W_p)
I_{sc0}	short circuit current at STC (A)
V_{oc0}	open circuit voltage at STC (V)
I_{max0}	maximum current at STC (A)
V_{max0}	maximum voltage at STC (V)
S	surface (m^2)
T_c	cell temperature (°C)
I_{rr}	Irradiance (W/m^2)
I_{rra}	Irradiation (Wh/m^2)
IL_{pv}	relative losses of short-circuit current (%)
I_{pvc}	measured short-circuit current of PV modules with cleaned glazing (A)
I_{pvd}	measured short-circuit current of PV modules with dirty glazing (A)
E_{pv2}	power production of sub-array 2 (kWh/day)
E_{pv3}	power production of sub-array 3 (kWh/day)

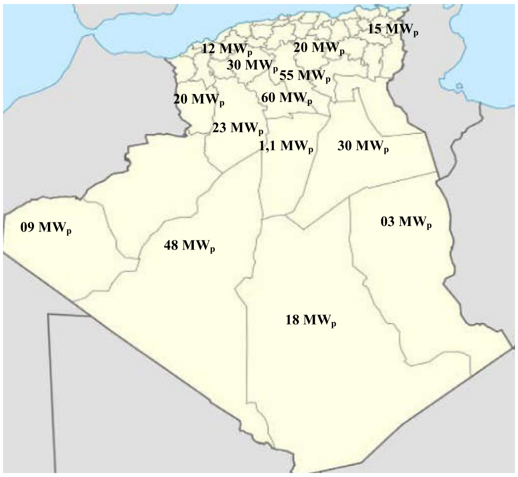

Fig. 1. Distribution of installed grid-connected PV across Algeria.

Our experiences in the Algerian Sahara show that power losses due to dust are valued at an average of 4% for a dust accumulation which exceeds two months [3]. Schill et al. [4] reported a drastic decrease in PV module efficiency by heavy soiling of the glass surface. The efficiencies dropped to 20% of the initial values within 5 months. In Australia, Tanesab et al. [5] investigated the contribution of dust to the long-term performance degradation of various photovoltaic (PV) modules that have been operating for almost eighteen years without any cleaning procedures at the Renewable Energy Outdoor Testing Area, Murdoch University. Recently, Maghami et al. [6] reviews and evaluates key contributions to the understanding, performance effects, and mitigation of power loss due to soiling on a solar panel. Their study also present a few cleaning method to prevent from dust accumulation on the surface of solar arrays. In this work, an investigation was focused on soiling impact on grid connected photovoltaic system efficiency. In this sense, tests were carried out on PV modules with and without soiling on their surfaces. The photovoltaic principle is based on the amount of generated photo-currents by the absorption of light. Dust particles quantitatively prevent the penetration of the photons in the semiconductor material. Hence, our objective is to investigate the dust impact on the performance of grid connected PV generator. This approach is illustrated in case study of CDER's

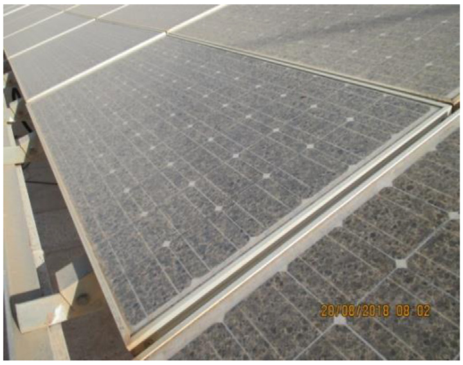

Fig. 2. Example of soil accumulation on PV modules at Algiers site.

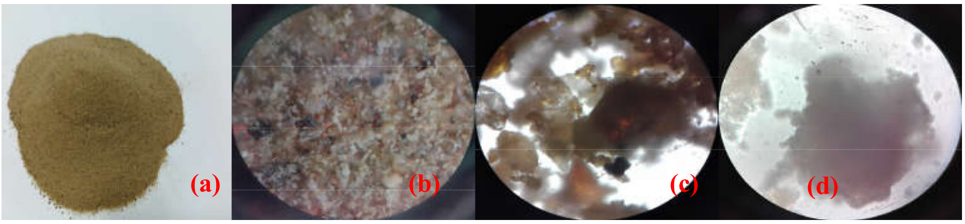

Fig. 3. Coastal dirt sample at (a) 1×, (b) 10×, (c) 40× and (d) 100× magnification.

grid connected PV system. Our contribution could be of great importance to PV solar system in Algeria and all other countries with similar weather conditions.

2. Methodology and materials

2.1. Site of experimentation

In the beginning, a study was conducted in coastal region, in Northern of Algeria (36.8°N, 3°E and 345 m). This region takes profit from a climate that is wet. Indeed, it is ranked in the first climatic zone, with an estimated yearly solar radiation of 2580 kWh/m^2 on a titled plane to the latitude of the site [7]. The Algerian coastal regions are characterized by strong black carbon emissions and moist climate, where, the carbon and dust particles are stuck on surfaces. The small particles accumulation during a long period was due to the natural elimination phenomena of great particles by wind or rain. These natural effects are in accordance with previous ascertaining of Javed et al. [8]. The dirt samples from coastal area, as shown in Fig. 3. These images show the collected dust samples on PV modules with particle aggrandizement.

2.2. PV system description

In this work, we have two experimental PV systems. The first, the PV system contains six m-crystalline modules I-75/12 with total power of 450 W_p in STC, covering an area of 3.45 m^2 tilted 36° from horizontal plane. This system is used for electrical parameters test of PV modules with dirt effect. The second is a grid connected PV system, it has includes three PV sub-arrays of 30 m-crystalline PV modules I-106/12 with a total module area of 64.8 m^2 (Fig. 4).

Each one power output at standard test conditions (STC) (1000 W/m^2, 25 °C) was 3.15 kW$_p$ interconnecting 15 modules in series and 2 in parallel. The modules are titled 27° from horizontal plane. Each sub-array is connected to a single-phase inverter through an electrical enclosure containing the required electrical protections. Fig. 5 show the grid connected PV system configuration.

Fig. 4. Grid connected photovoltaic generator on roof.

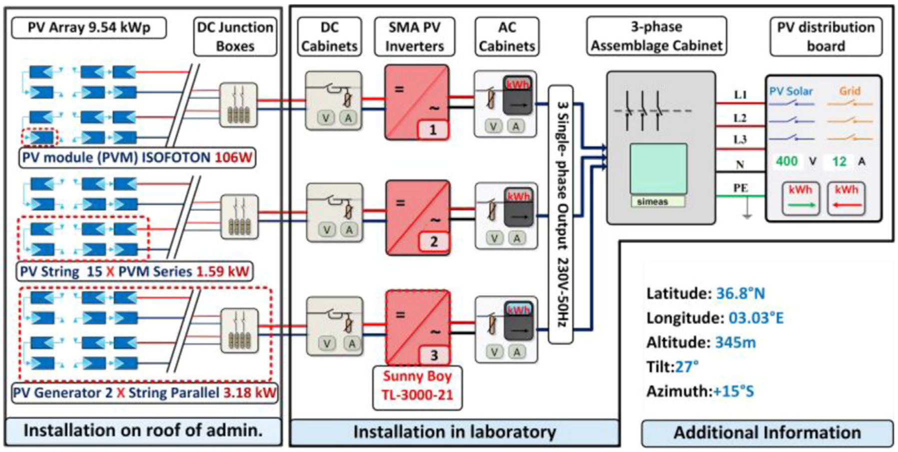

Fig. 5. Grid connected photovoltaic system configuration.

Table 1. Parameters of PV modules in standard test conditions.

Parameters in STC	P_p [W]	I_{sc0}[A]	V_{oc0} [V]	I_{max0} [A]	V_{max0} [V]	S [m^2]
I-75/12	75	4,67	21,6	4,34	17,3	0,57
I-106/12	105,5	6,65	21,54	6,08	17,36	0,72

The AC sides of the three inverters are connected to a first electrical enclosure to allow creating a three-phase system, which are connected to a second electrical enclosure to permit the connection to the low voltage electrical grid terminal. The produced PV energy is consumed firstly locally by the loads of the laboratory, the extra is injected into the electrical grid. Inverters installed on the power plant are of type Sunny Boy SB 3000 TL ST-21 from SMA. The monitoring of the power plant is assured by Sunny Web-Box (SMA product) which allowing to collecting and documents electrical data from inverters. Through the Sunny Sensor-Box (SMA product), the data of solar radiation and PV modules temperature are also recorded. The parameters of PV modules given by manufacturers in STC are shown in Table 1.

3. Results and discussions

PV system analysis will be given in this section, such as power production, performance and losses due to dirt effect. It will allow us to check how the system is behavior and interpret all results.

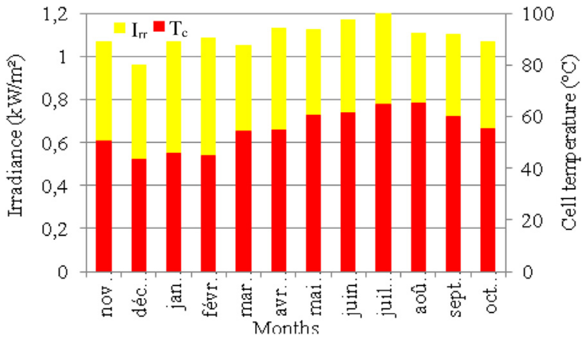

Fig. 6. Monthly variation of maximum cell temperature and irradiance.

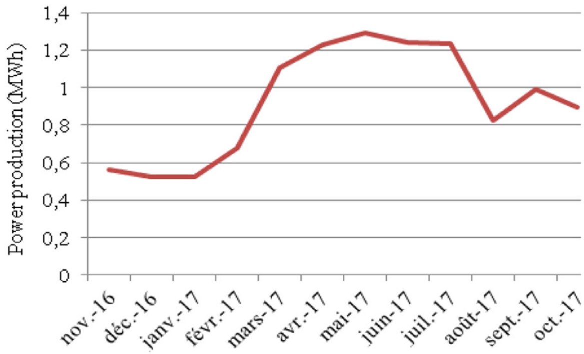

Fig. 7. Yearly variation of grid connected PV production.

3.1. Grid connected PV system power production

The Fig. 6 below shows the monthly maximum irradiance (I_{rr}) on PV modules plan and the cell temperature (T_c) in year. We then notice that the radiation is more importunate in summer. When the cell temperature rises above 60 °C, the irradiance on inclined surface has more than 1 kW/m^2.

The monthly energy delivered by grid connected PV array is shown by Fig. 7. This energy vary with the seasons proportionally to the monthly global radiation and delivered in to the inside grid of renewable energy center. The energy produced during one year is 19417 kWh. This energy varies 525 KWh in January to 1295 kWh in May. The energy fed into the grid in this period is 11287 kWh.

3.2. Dirt effects on power and I–V curve

The PVPM-2540C instrument used in our experience is limited in power. For this reason, we used a small PV system for electrical parameters test (First PV system), which may be shows an approximate idea of dirt effect on PV generator characteristics. The dirt accumulation affects the electrical characteristics of PV modules, as it mainly depending of transmittance surface. The experimental I-V curves of PV generator with and without dirt in coastal region are illustrated in Fig. 8 below. The significant disparity is observed with dirty and cleaned glazing surface.

Dirt level deposited on the PV generator surface is accumulated during almost one month and half after the last cleaning in coastal region, as consequence, causing a variable decrease of short circuit current during day. Fig. 9 shows the daily evolution trend of short circuit (SC) current losses due to soiling effects. Where, the short circuit current losses are very important during the day with a maximum exceeding 14%. The parameter of relative losses of short-circuit current is calculated by Eq. (1). Where I_{pvc} and I_{pvd}, respectively, are the measured short-circuit current for cleaned and dirty glazing of PV modules.

$$\mathrm{IL_{pv}} = 100 \cdot \left(\frac{\mathrm{I_{pvc}} - \mathrm{I_{pvd}}}{\mathrm{I_{pvc}}} \right) \tag{1}$$

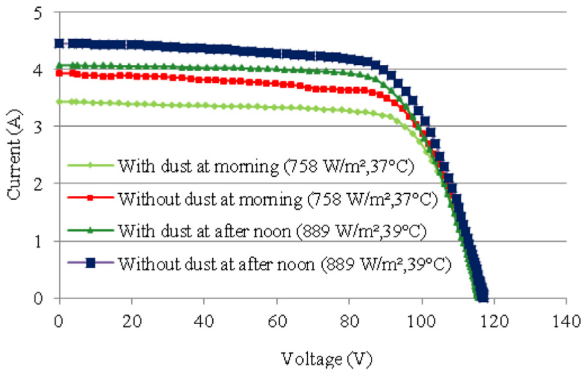

Fig. 8. Example of I-V curves of clean and dirty modules.

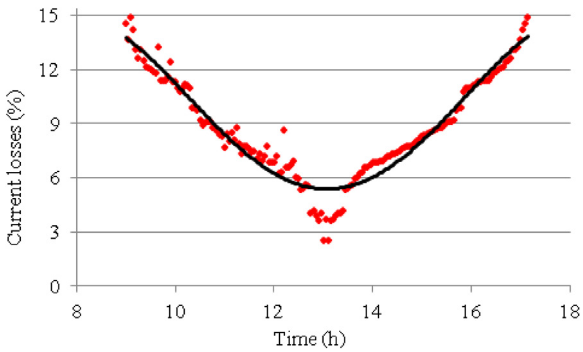

Fig. 9. Example of daily evolution of short circuit current losses.

Table 2. Power production versus irradiation with dirt effect during one month.

Day number	5	6	7	8	9	10
Date	09/08	13/08	14/08	03/09	04/09	06/09
I_{rra} [kWh/m^2/day]	7,072	7,124	7,071	7,100	7,301	7,158
E_{pv2} [kWh/day]	15,532	15,563	15,011	14,952	14,414	13,96
E_{pv3} [kWh/day]	17,188	16,934	16,413	16,335	15,384	14,895

3.3. Dirt effects on grid connected PV power production

Fig. 10 shows an example of dirt effects on power production of second PV system. Where I_{rra} is the incident solar irradiation amount, E_{pv2} is power production of sub-array 2 and E_{pv3} is power production of sub-array 3. Before cleaning, sub-arrays 2 and 3 have almost the same production for the same incident solar irradiation amount. After cleaning of sub-array 3, we noticed a disparity of energy production between sub-arrays 2 and 3. And also the production continues to decrease after one month and half of exposure, for almost the same incident solar irradiation (Table 2).

4. Conclusion

In this study we present the grid connected PV system installed in CDER-Algeria. An analysis of PV system performance was carried out in order to observe the effect of dirt in coastal regions. We report a significant decrease of short circuit current and PV power production by soiling on the glass surface. The nature of soiling and pollutants varies from area to area throughout North Africa. In coastal regions heavily occupied by people, the soiling is caused by the strong air pollution with a particles mixture of black carbon and dust. The average reduction in the short circuit current during the day is around 8.79% with more than one month of outdoor exposure after the last

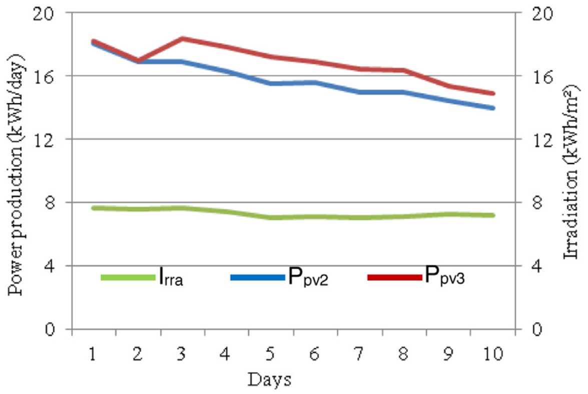

Fig. 10. Example of power production evolution versus incident energy.

cleaning in summer period. We can notice that power losses are dependent the sunlight incident angle. The PV power production losses are an average of 8001%. These results can be used to size a PV system and forecast energy production by taking into consideration the soiling effects.

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