Impact of climatic conditions on photovoltaic modules performance

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***Abstract*— Significant advances have been made in PV systems within the last few decades. However, designers still face challenges related to the effects of climate conditions on PV systems performance. Climatic conditions such as temperature, humidity, wind velocity, solar irradiation and dust accumulation can effect significantly on the performance of PV modules. This experimental work aims to determine the effect of two parameters (PV module temperature and dust accumulation) on output power of solar PV panels in arid area. The experimental results showed the effect of dust accumulation in drooping of photovoltaic energy production, with decreasing by 5.35%, 0.38% and 5.94% in short circuit current, open circuit voltage and maximum power output respectively compared to cleaned PV panel. In the other hand results showed that the open circuit voltage and maximum power of non-cooled PV module are lower than cooled module by 5.64% and 6.35% respectively.**

Keywords*— temperature, output power, dust accumulation, photovoltaic, cooling.

I. INTRODUCTION

Global energy consumption has risen in recent years mainly due to the high population increase, the main source of energy demand is coming from fossil fuels (81%), 5.7% nuclear power and the contribution of renewable energy sources still weak such as biofuel and waste (10%), hydro (2.3%) and others: solar, wind, geothermal, heat, among others 0.9% . There are several benefits of renewable energy sources but most important one is that it can reduce the carbon dioxide emission [1].

Among various renewable energy sources, solar energy is an abundant energy source which provides 4000 trillion kWh of insolation per day. Solar energy can be harnessed to produce electricity in two ways, photovoltaic (PV) and concentrating solar power (CSP). The cost of the photovoltaic energy is still higher as compared to conventional sources of power generation, and this is a trouble facing the use of photovoltaic energy systems [2].

The performance and efficiency of photovoltaic installations are affected by two environmental factors, which are meteorological conditions and geographic locations [3]. Climatic conditions effect strongly on the performance of photovoltaic modules especially in arid and desert environments where the weather conditions are harsh and hinder the photovoltaic conversion, among these meteorological conditions, there are two important parameters, which are the ambient temperature and dust accumulation, these two parameters have significant effect on the degradation of PV systems performance.

Major part of solar irradiation received by solar cells is converted into heat energy which lead to increase in PV cells temperature. This not only reduces the electricity generation efficiency but also affects the lifetime of PV panels. Most of previous studies and research found that PV performance droops with the increase in module temperature [4]. This aspect constitutes a huge obstacle because the PV module efficiency decreases at a rate of 0.4-0.65% with a one-degree increment of the solar cell temperature [5]. Many efforts and researches have been performed in recent years to find innovative technics and solutions to reduce the PV cells temperature and improve their performance by different cooling mechanisms such as water pulverization on the front surface of PV panel, integration of PCM materials in the backside of PV module, hybrid (photovoltaic/thermal) systems [6-8].

Recently the accumulation of dirt (e.g. dust, pollen and bird dropping) on the glass surface of photovoltaic modules has been receiving more attention. This accumulation is known as soiling and is considered as one of the most important environmental factors influencing PV systems performance [9]. The accumulation of dust on the surface of PV module reduces the glass cover transmittance and hence decreases the amount of solar irradiation reaching the cells, thereby also affecting the power generation performance of the PV module [10, 11]. Many researches have been performed to find effective solutions to mitigate the impact of dust deposition on solar panels, using anti-soiling coated surface [12] or by cleaning with water [13].

The main objectives of this research is to investigate experimentally the effect of PV cell temperature and dust accumulation on the power output of PV modules installed in arid area (Ouargla, Algeria).

II. Experimental Procedure

A. Experimental setup

This study consists of two sections, the first is an experimental investigation of the effect of dust accumulation on PV systems performance. Two 50W polycrystalline photovoltaic solar modules were used in this part one cleaned and the other left dusty for a period of 20 days without cleaning to study the effect of dust accumulation on output power of PV panels **Fig.1.**

The second section is an experimental evaluation of the effect of water-cooling on the performance of photovoltaic modules, the used cooling technic based on water pulverization on the front surface of PV module. Two 80W monocrystalline photovoltaic solar modules were used in this part, one with cooling and the other without cooling**.**

B. Test measurments

The experimental setup consisted of a variable resistor (rheostat) considered as a load resistor , a digital multi-meter for measuring the module power output in terms of current and voltage **Fig.2.** The measurements were recorded in the external climatic conditions during clear days at the University of Ouargla, Algeria. The solar modules should face to the south with a tilt angle of the latitude 32º for the location of Ouargla, Algeria. **Table.1** shows the electrical specifications for the module under STC conditions.

TABLE I
TECHNICAL SPECIFICATIONS OF THE PV MODULES UNDER STANDARD TEST CONDITIONS (STC).

Parameters	**Specifications**	
Technology	polycrystalline	Monocrystalline
Maximum power (W)	50 W	80 W
Maximum voltage (V)	17.2	17.2
Maximum current (A)	2.9	4.65
Open circuit voltage (V)	21.6	21.6
Short circuit current (A)	3.2	5
Area (mm^2)	1042*462	1195*541

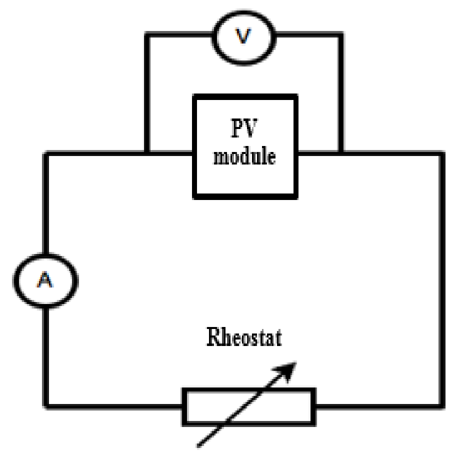

Fig. 2. Electrical circuit measurements.

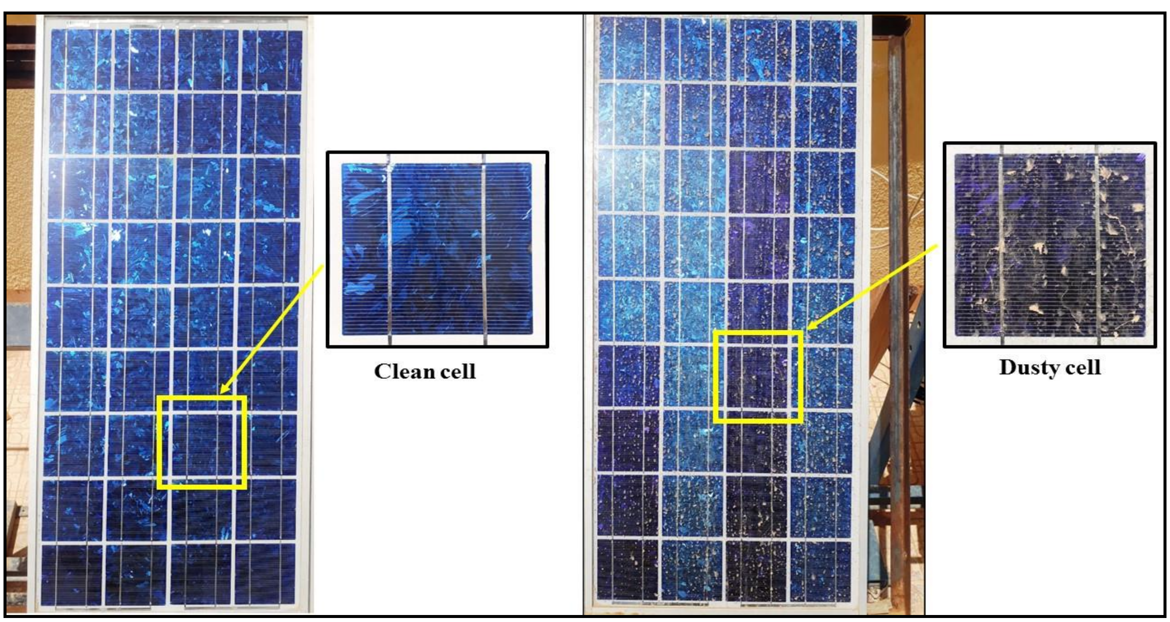

Fig. 1. Photo of dusty and clean PV modules.

III. RESULTS AND DISCUSSION

A. *Effect of dust accumulation*

A dusty solar module compared with a clean module which was taken as reference. Both PV and IV curves were drawn in excel sheet. Maximum power is obtained at maximum voltage and maximum current condition. **Fig (3 and 4)**, shows the obtained I-V and P-V curves of PV module samples, recorded under clean and dusty conditions.

The results shows lower values for both I-V and P-V curves of dusty PV module after 20 days of exposure in externals conditions without cleaning compared to the clean module.

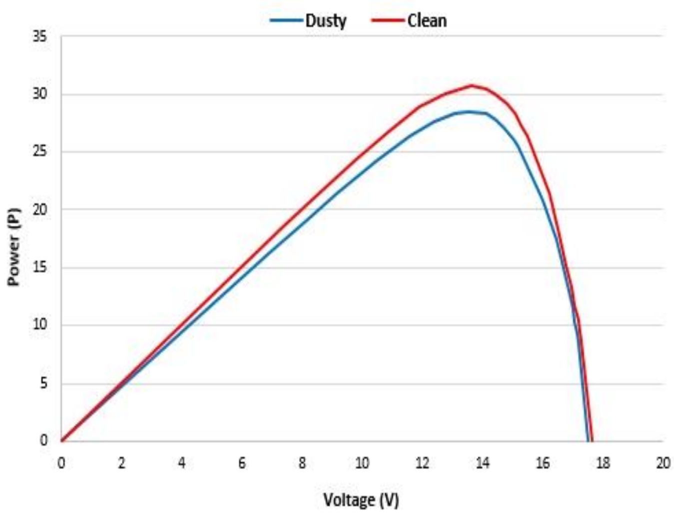

Fig. 3. P–V curves of dusty and clean PV modules.

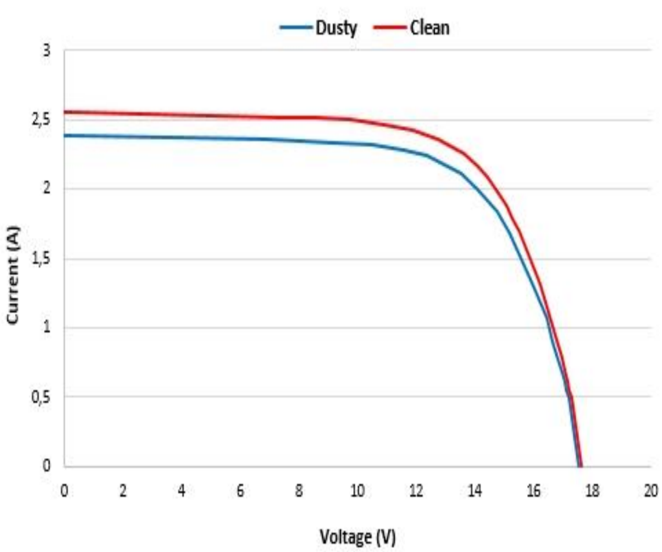

Fig. 4. I–V curves of dusty and clean PV modules.

These curves indicate a degradation caused by dust deposition on PV module's surface that decrease solar irradiation received by the solar cells. The discrepancy between these curves is expected to increase with the increase of dust accumulation on PV module's surface.
The effect of dust on the characteristic of electrical parameters of PV modules is shown in **Table II**.

I_{sc} and P_{max} are parameters significantly affected by dust deposition with a decrease about 5.35% and 5.94%, respectively. In contrast, V_{oc} output is less sensitive to dust accumulation and drop by 0.38% compared to values recorded in clean conditions.

TABLE II
PV MODULE PARAMETERS FOR CLEAN AND DUSTY MODULES.

parameters	Clean module	Dusty module	Variation %
Pmax (W)	34.63	32.57	5.94
Isc (A)	2.8	2.65	5.35
Voc (V)	18.33	18.26	0.38

B. *Effect of temperature*

P-V and I-V curves of cooled and non-cooled PV modules are shown in Fig 5 and 6. The water pulverization on front surface of PV module causes a noticeable improvement in output power of the cooled PV module, as shown in Fig. 5. The maximum value of output power without cooling system equals 72.99 W, whereas its value for PV module with water cooling system equals 78.01 W. Consequently, an increase in the output power of 6.35% of the PV module is observed in case of using water-cooling. In the other hand an increase of about 5.65% was observed in open circuit voltage as a result of using water-cooling.

The effect of water-cooling on the characteristic of electrical parameters of PV modules is shown in **Table III**

TABLE IIII
PV MODULE PARAMETERS FOR COOLED AND NON-COOLED MODULES.

parameters	With cooling	Without cooling	Variation %
Pmax (W)	78.01	72.99	6.35
Voc (V)	21.15	20.04	5.65

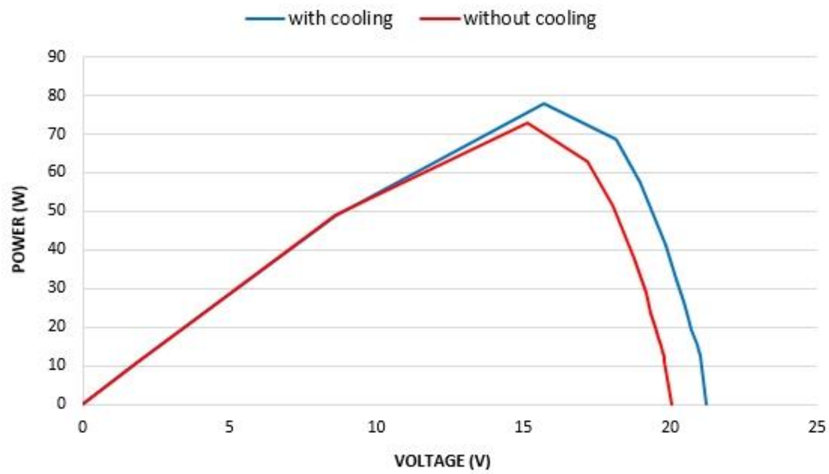

Fig. 5. P–V curves of cooled and non-cooled PV modules.

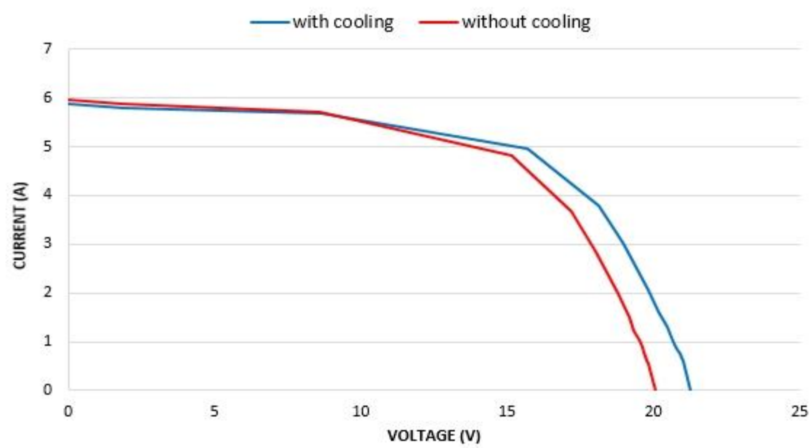

Fig. 6. I–V curves of cooled and non-cooled PV modules.

IV. Conclusion

Photovoltaic energy is one of the most widely used of renewable energy sources. However, photovoltaic energy conversion still low especially in regions where climatic conditions are harsh which lead to more decreasing in PV systems performance.

This study illustrated the significant effect of dust accumulation and PV module temperature on the performance of PV systems. The main results of this experimental work showed that the high temperature and dust accumulation could drop significantly the power output of photovoltaic modules. Therefore, regular cleaning and cooling technics are necessary in photovoltaic systems to benefit a desired performance.

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